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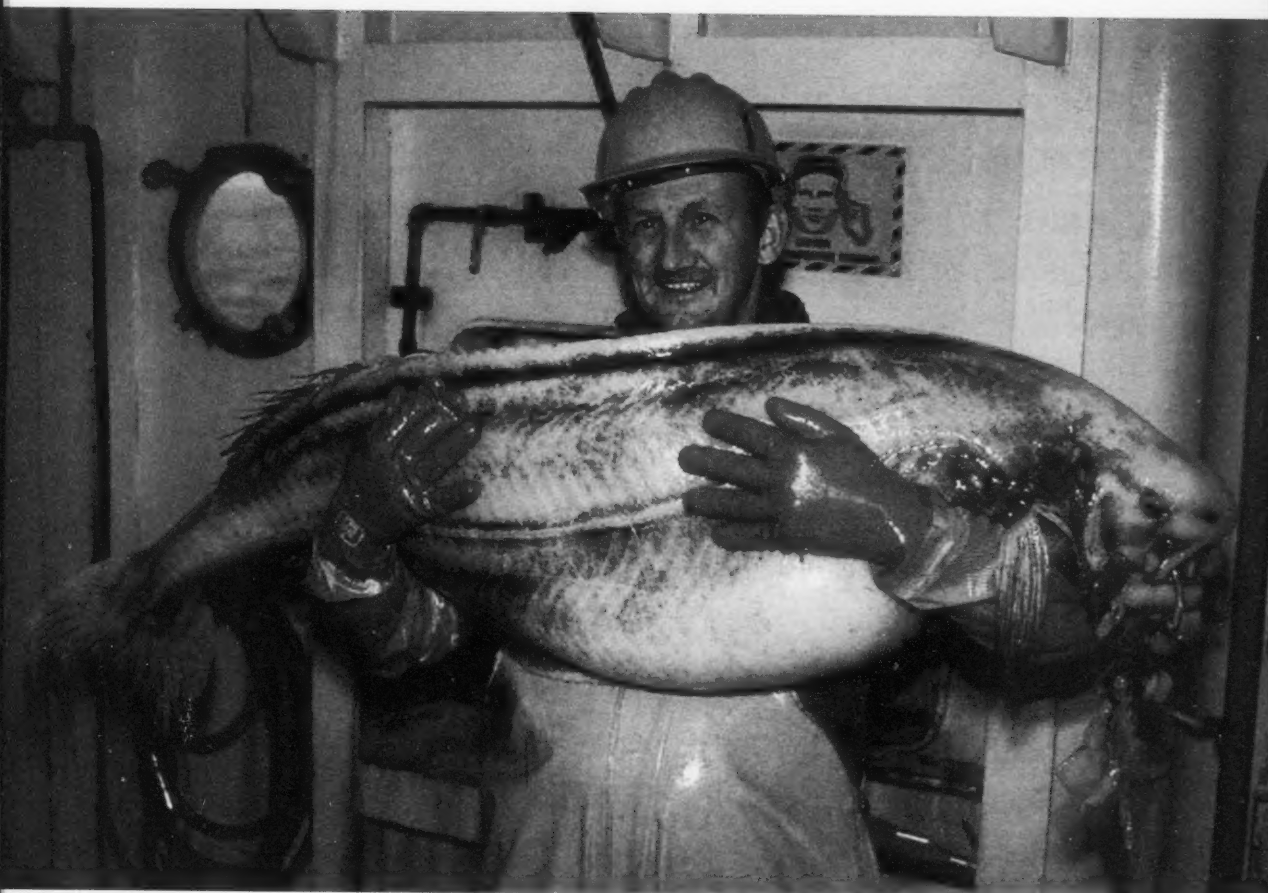

The Ragfish

Marine Fisheries REVIEW

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On the cover:
A 35.8 kg ragfish, *Icosteus aenigmaticus*, held by NMFS scientist Allen Harvison on a 1995 groundfish survey of the RV *Miller Freeman*. The specimen was caught off southern Oregon in a trawl that reached depths of 876 m. Photo by Robert Lauth, NMFS.

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The Ragfish, *Icosteus aenigmaticus* Lockington, 1880: A Synthesis of Historical and Recent Records From the North Pacific Ocean and the Bering Sea

GEORGE H. ALLEN

Introduction

The ragfish, *Icosteus aenigmaticus* (Fig. 1), with its soft musculature and cartilaginous skeleton, has been aptly characterized as a "puzzling fish with soft bones" (Fitch and Lavenberg, 1968; Moyle and Cech, 1996). Although external morphology has been described, most details of internal morphology and details of life history of this cold, deepwater species remain enigmatic and puzzling to science.

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Historically, ragfish have been collected sporadically from the Pacific Ocean continental shelf of North America beginning off southern California, extending northward to the Gulf of Alaska, along the Aleutian Islands, and then south to eastern central Japan. Commercial fisheries have taken ragfish from the surface waters of the North Pacific Ocean, the Gulf of Alaska, and the Bering Sea, in addition to relatively shallow coastal bays and inlets. Maximum depth of ragfish habitat off the continental shelf is unknown, as well as most factors of its life history. Only recently have detailed aspects of the species' early life history (ELH) been published (Matarese et al., 1984, 1989; Wing and Kamikawa, 1995; Wing et al., 1997). No specific study on the biology of adults, however, has been reported in the literature, except a preliminary note on fecundity (Allen, 1968).

ABSTRACT—Knowledge of the distribution and biology of the ragfish, Icosteus aenigmaticus, *an aberrant deepwater perciform of the North Pacific Ocean, has increased slowly since the first description of the species in the 1880's which was based on specimens retrieved from a fish monger's table in San Francisco, Calif. As a historically rare, and subjectively unattractive appearing noncommercial species, ichthyologists have only studied ragfish from specimens caught and donated by fishermen or by the general public.*

Since 1958, I have accumulated catch records of >825 ragfish. Specimens were primarily from commercial fishermen and research personnel trawling for bottom and demersal species on the continental shelves of the eastern North Pacific Ocean, Gulf of Alaska, Bering Sea, and the western Pacific Ocean, as well as from gillnet fisheries for Pacific salmon, Oncorhynchus *spp., in the north central Pacific Ocean. Available records came from four separate sources: 1) historical data based primarily on published and unpublished literature (1876–1990), 2) ragfish delivered fresh to Humboldt State University or records available from the California Department of Fish and Game of ragfish caught in northern California and southern Oregon bottom trawl fisheries (1950–99), 3) incidental catches of ragfish observed and recorded by scientific observers of the commercial fisheries of the eastern Pacific Ocean and catches in National Marine Fisheries Service trawl surveys studying these fisheries from 1976 to 1999, and 4) Japanese government research on nearshore fisheries of the northwestern Pacific Ocean (1950–99). Limited data on individual ragfish allowed mainly qualitative analysis, although some quantitative analysis could be made with ragfish data from northern California and southern Oregon.*

This paper includes a history of taxonomic and common names of the ragfish, types of fishing gear and other techniques recovering ragfish, a chronology of range extensions into the North Pacific and Bering Sea, reproductive biology of ragfish caught by trawl fisheries off northern California and southern Oregon, and topics dealing with early, juvenile, and adult life history, including age and growth, food habits, and ecology. Recommendations for future study are proposed, especially on the life history of juvenile ragfish (5–30 cm FL) which remains enigmatic.

There have been, and still are, difficulties with the taxonomy and classification of the species. Early ragfish descriptions and taxonomy were unaware of the changes in morphology from juvenile to adult stage. Clemens and Wilby (1961: 236), in combining juvenile and adult forms in the same species, summarized these changes as follows:

> ". . . the pelvic fins, which are loosely attached in the young, become lost; the limp skin encroaches more and more over the anterior ends of the dorsal and anal fins thus giving a low count of the rays except under dissection; the modified scales disappear; the character of the pectoral and caudal fins is changed from round to pointed in the former, and from round to broadly emarginate in the latter; the yellow color and purplish spots change to a more somber brown as the adults attain greater size."

Not surprisingly, Lockington (1880), in his initial description of the species, named juveniles as "spotted ragfish," *Icosteus aenigmaticus*, while Bean (1887) called the first adult he described the "brown" ragfish, *Acrotus willoughbyi*. Goode and Bean (1895) used the common name of "fantail ragfish" as did many subsequent authors (Regan,

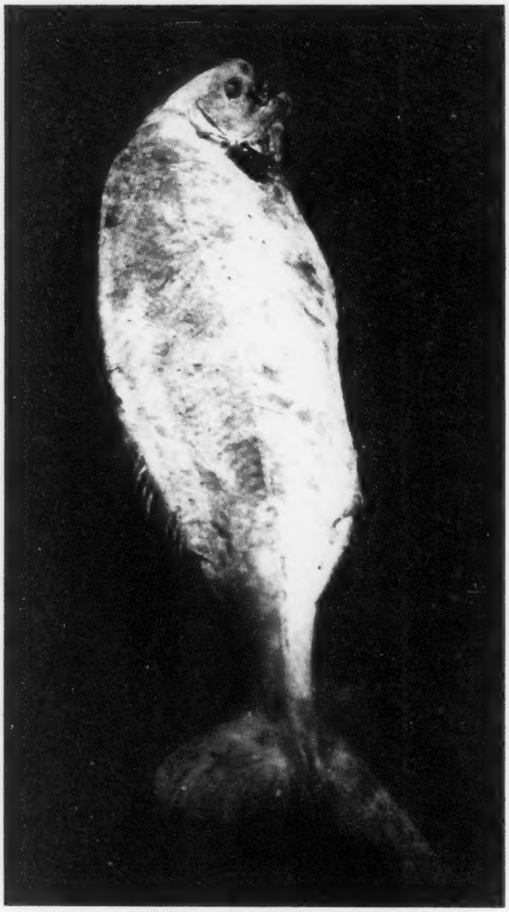

Figure 1.—Male ragfish landed 17 July 1989 at Crescent City, Calif., caught by trawler *Miss Jo Anne* (Newt Percy, skipper) 25 n.mi. due west of Point St. George, along 486 fm (890 m) contour. Specimen metrics: 139 cm SL; deepest body depth 35 cm; weight 102 kg. (Photograph by G. Allen).

1923; Clemens and Wilby, 1949; Kamohara, 1962; Abe, 1963). Some reports omitted a common name, while others used the generic ragfish or "rag" fish (Higgins, 1921; Thompson, 1921). Crawford (1927) applied ragfish to an adult specimen, while Prichard (1929) applied the term to a juvenile, suggesting that the adult and juveniles were being considered as the same species. Barnhart (1936) bucked the unifying trend by using "speckled ragfish" for the juvenile and "giant ragfish" for the adult. Schultz (1936), however, employed the common name ragfish to both juveniles and adults at the species level, but he used "ragfishes" for the family Icosteidae (juveniles) and "pelagic fish" for the family Acrotidae (adults).

Following a hiatus in general scientific work associated with World War II, Fitch (1953) used "ragfish" in reporting on both juveniles and adults, as did Wilimovsky (1954). No mention was made of English common names when Japanese authors began reporting in English on ragfish juveniles recovered off Japan (Abe, 1954). Kobayashi and Ueno (1956) omitted any English common name but did note that the caudal fin as "very broad and fan-like," with a pictured specimen (69 cm TL) of an adult showing the tail slightly emarginate. Kamohara (1962:5) listed only the Japanese common name for a described ragfish but also reported on the tail ". . . the peduncle widening posteriorly to support the fan-shaped caudal." The common name of ragfish "became applied consistently when the juvenile and adult stages were recognized as the same species (Bailey et al., 1960; Clemens and Wilby, 1961).

Fishermen commonly contribute a plethora of common names for fish they catch, but when rarely encountered species are caught, the common name applied by taxonomists, if known, usually suffices. For the ragfish an exception may have been whalers apparently using their own unique common name (Cowan, 1938:97): "Dr. Robbins is confident that the 'bastard halibut' of the whalers is identical with the brown ragfish." I feel it likely that the general public tends to consider beached large female ragfish as some sort of Pacific salmon.

Gross external morphology and coloration differences between adult ragfish (Fig. 2A–E) and juvenile ragfish also influenced the history of taxonomic studies of the species. Günther (1887:46), after reviewing the literature and examining two juveniles in his collection, named the species *Schedophilus enigmaticus* Steindachner, even though Steindachner, in an 1881 paper, used *Icosteus enigmaticus*. Günther placed ragfishes in the family Coryphaenidae, stating that he had failed to find in published descriptions anything that would warrant a generic separation from *Schedophilus* or the creation of a distinct family "Icosteidae." Lockington (1880) also puzzled over taxonomic status when he listed the ragfish in the family Blennidae. Bean (1887) noted that the adult ragfish he described appeared to be closely related to *Icosteus*, but he did not specifically designate a family.

Reflecting the early tentative taxonomies, Dean et al. (1923:646) listed four kinds of "ragfishes" under the family Icosteidae (*Acrotus*, *Icicthys*, *Icosteus*, and *Schedophilius medusophagaus*). Both juveniles and adults were combined under one species (*Acrotus wil-*

loughbyi Bean) and family Acrotidae (Ulrey and Greeley, 1928). The "rule of priority," however, assigns the name to Lockington with "ragfish" the official common name, the genus *Icosteus*, and family Icosteidae (Wilimovsky, 1954; Fitch and Lavenberg, 1968; Miller and Lea, 1972; Hart, 1973; Wheeler, 1975; Nelson, 1976; Matarese et al., 1984; Moyle and Cech, 1996).

There also has been difficulty in assignment of the family to higher taxa due to a continued puzzlement over ragfish evolutionary history. Thus Regan (1923: 612) wrote: "The exact systematic position of the Icosteidae is uncertain, but the great development of cartilage and the weakness of the bones is evidently secondary, and there is nothing in their organization to prevent the assumption that the Icosteidae represent a specialized and somewhat degenerate development of the Perciform type." Berg (1940:494) accepted Regan's opinion, and placed the family Icosteidae in a separate order Icosteiformes (Malacichthyes). Matarese et al. (1984), in their study of larval forms up to 2.8 cm in length, identified both blennoid and stromatoid morphological features. They summarized the present ragfish status as follows: "The systematic position of this group and its designation as an order or suborder is not well established. Greenwood et al. (1966) considered it a suborder of Perciformes (Icosteoidae) while Gosline (1973) elevated it to an order, Icosteiformes, a probable perciform derivative" (Matarese et al., 1984:576).

A black-and-white drawing of excellent quality of an early 26 cm long juvenile showing external morphology and the pattern and texture of the skin was published in Günther (1887:46, Plate XLIV, *Schedophilus enigmaticus*). Goode and Bean (1895) conveniently placed line drawings of a juvenile and an adult together (Plate LXII), and included illustrations of other species with close affinities (*Icicthys lockington, Centrolophus pompilus, Schedophilus medusophagus*) (Plates LXI, LXII). Recent photographs of a juvenile appeared in Fitch (1953) and Fitch and Lavenberg (1968). Illustrations of adults were published by Jordan and Evermann (1898:973) and Clemens and Wilby (1961:333). A color illustration of an adult can be found in Eschmeyer and Herald (1983:Plate 46). The most appealing historical photograph of an adult ragfish is that of the Yecny family arranged beside a suspended 152 cm (5 ft) specimen caught while sport fishing on 20 May 1940 from a breakwater at Monterey Bay, Calif. (Bolin, 1940:287). The most accurate depiction of the general shape and skin pattern of juvenile and adult ragfish is that in Hart (1973:386). Such general shape and skin patterns are evident in photographs of juvenile and adult specimens that only came to my attention during March 2002 (Fig. 3A, B).

Prior to August 1999, I had assembled over 200 unpublished and published historical records on ragfish, with some historical records added in December 1999 and February 2000. During August

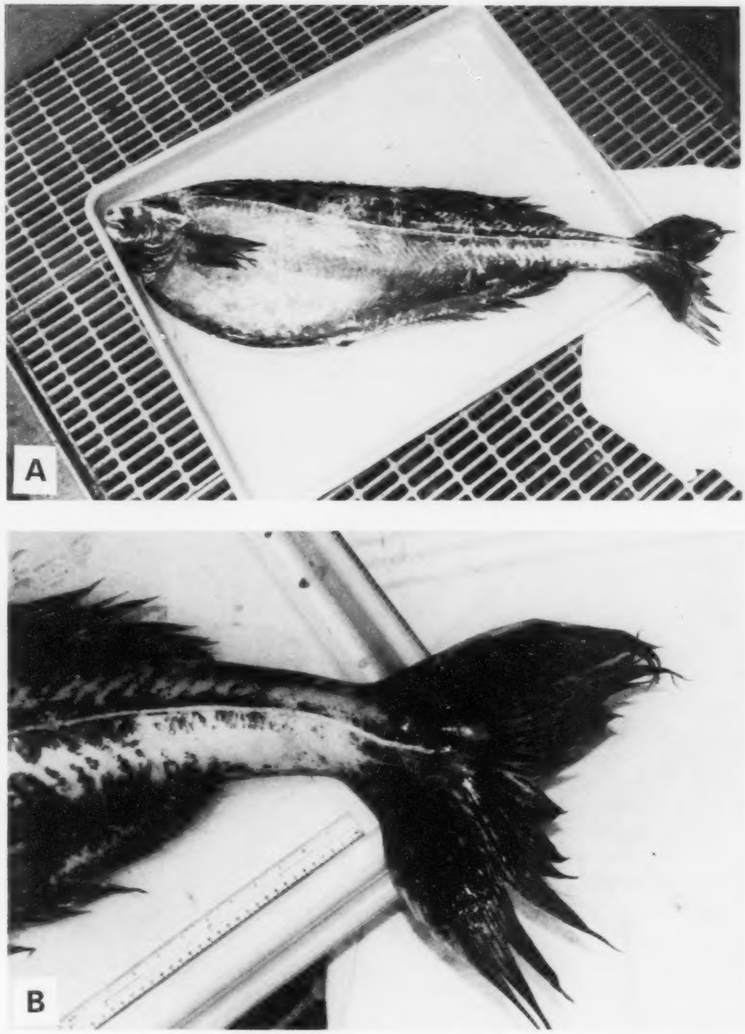

Figure 2A, B.—Selected morphological features of an adult ragfish, *Icosteus aenigmaticus* Lockington, caught May 2002 as photographed by Gus Theisfeld. A. Lateral view of fresh specimen. Weight 50 pounds. B. Lateral view of caudal peduncle and raised lateral line extending to the end of the cartilaginous vertebral spinal column.

1999, I received from J. Heifetz[1] data on 620 ragfish specimens incidentally observed and recorded during studies on commercially important species taken by U.S. fishermen from California to the Bering Sea. These records from the NMFS Alaska Fisheries Science Center, Seattle, Wash., and records of ragfish existing in published literature, were primarily used to enlarge our knowledge of ragfish distribution, both geographically and ecologically. Much new biology and life history aspects of the ragfish came principally from the records of specimens taken by bottom trawlers operating off northern California and southern Oregon and by the California Department of Fish and Game (CDFG), Oregon Department of Fish and Wildlife (ODFW), and by the fisheries department at Humboldt State University (HSU), Arcata, Calif.

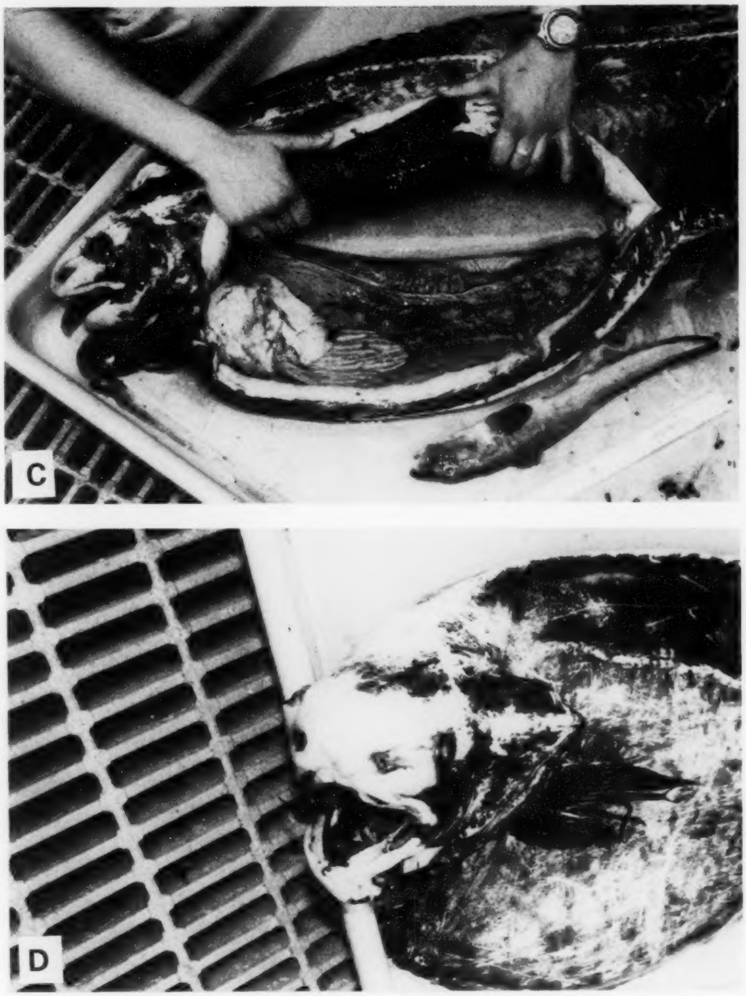

Figure 2C, D.—C. Lateral view of internal organs in situ in abdominal cavity with ovary dorsal to viscera and no air bladder. Eel pout (Zoarcidae) removed from throat and esophagus shown above 12″ ruler. D. Frontal view of broad head with terminally positioned eyes and nostrils.

Materials and Methods

Data Sources

Historically, ragfish have come to science through fishermen and citizens who retain specimens and voluntarily deliver them to fisheries management personnel, museum curators, and ichthyologists. My first experience with ragfish was in this tradition when, in 1958, a crew member of a commercial bottom trawler (F/V *Sitka*) operating out of Eureka, Calif., prevented the discard at sea of a single large female ragfish. The crew member, a personal acquaintance, phoned me from the dock to come and examine the fish. I observed a running-ripe female that subsequently became one of the four females in a preliminary study of ragfish fecundity (Allen, 1968).

From 1958 through 1989, a total of 39 fresh specimens taken by commercial trawlers landing catches mainly at Fort Bragg, Eureka, and Crescent City, Calif., were transferred to HSU for study along with another 44 specimens from northern California and southern Oregon, recorded and catalogued by the CDFG (Table 1). A mail survey in 1977 of 14 museums and agencies (excluding CDFG) with known fish collections produced 67 historical records. In 1998 and 1999 state and Federal fisheries biologists in Juneau and Petersburg, Alaska, forwarded 16 more ragfish records. Additional records of California ragfish recovered in 2000 were not incorporated into this report due to my desire to bring the report to a conclusion. Historical records were mainly of larger juveniles and mature females (Table 2).

Other important sources of ragfish data were found in published and institutional archival reports by governmental agencies engaged in monitoring and research associated with the management of North Pacific Ocean fisheries. One of the longest and most detailed of these studies was on early life history (ELH) stages (eggs and larvae) of commercially important marine fish species sampled from 1951 to 1984 by the California Cooperative Fisheries Investigation (CalCOFI). The sampling grid overlays three coastal zoogeographic provinces, a coastal upwelling zone, and

[1]Heifetz, J. National Marine Fisheries Service, Auke Bay Laboratory, 11305 Glacier Hwy, Juneau, AK 99801-8626.

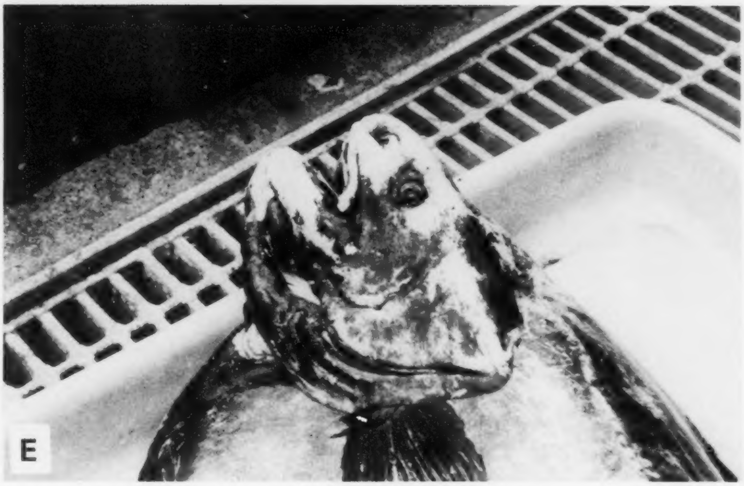

Figure 2E.—Lateral view of head showing snout profile, and undamaged gills and isthmuth.

Table 1.—Number and sex of ragfish *Icosteus aenigmatic* Lockington, in historical records, 1880–2000.

Agency or institution and acronyms	Number of specimens: Male	Female	Unknown	Total
California Department of Fish and Game (CDFG)	2	13	16	31
	0	3	10	13[1]
	2	16	26	44
Humboldt State University (HSU)	11	23	2	36
	0	0	3	3[1]
	11	23	5	39
Mail survey 1976–77:				
Oregon State University (OSU)	1	1	21	23
California Academy of Science (CAS)	1	3	7	11
University of Washington School of Fisheries (UW)	1	0	7	8
British Columbia Provincial Museum (BCPM)	0	0	7	7
Six institutions 4 records or less[2]	0	0	18	18
Additions 1999, 2000[3]	0	3	15	16
	16	46	106	166

[1] Additional CDFG records located December 1999, and of preserved juveniles examined at HSU February 2000.

[2] University of California Los Angeles (UCLA); University of British Columbia (UBC); Scripps Institution of Oceanography (SIO); Alaska Department of Fish and Game, Auke Bay Labatory (ABL); United States National Museum (USNM); Moss Landing Marine Laboratory (MLML).

[3] Alaska records from personal communications with Bracken (text footnote 10), Wing (text footnote 11), Kondro (text footnote 12) and in 1995, and Wing (text footnote 13).

three oceanic water masses of the eastern North Pacific (Moser et al., 1993; Moser et al., 1994). Other recent records of ELH stages of ragfish are those from the eastern North Pacific Ocean where specimens were sampled during studies on commercial groundfish stocks of the continental shelf from Sitka to Dixon Entrance (Wing and Kamikawa, 1995; Wing et al., 1997). An international effort during the 1990–91 fishing seasons to document incidental catches of fish, mammals, and birds of conservation concern in major North Pacific commercial surface gillnet fisheries for squid and salmon also recorded ragfish (INPFC).[2] Reports on three national fisheries listed 27 records of ragfish taken from generalized areas (Japan: McKinnell et al.[3]; China: Yeh et al.[4]; Korea: Park et al.[5]). No other data were included since the studies focused on the incidental catch of animals of international conservation concern.

Analysis of Historical Data

Most fresh adult ragfish delivered to HSU were measured (cm) for total length (TL) and standard length (SL), and for total and gonad weight (gm). Data on depth, location, and time of capture were furnished either by the person capturing the specimens or by CDFC biologists who examined the ragfish on the docks. Most useful data on 66 specimens >35 cm came from seven institutions (HSU, 34; CDFG, 15; CAS, 8; ABL, 3; BCPM, 3; UBC, 2; MLML, 1).[6] Smaller specimens (<35 cm SL) recorded in museum collections were immature juveniles, with available records containing only scant biological data. Data on juveniles were used primarily in studying distribution. CDFG ragfish records supplied by John Fitch[7] were for fish landed mainly south of Cape Mendocino, and measurements were similar to those taken on HSU specimens. Miscellaneous observations on some fish in HSU and CDFG included notes on stomach contents, whether eggs were running from the vent, and a few had measurements on length and weight of ovaries.

Metrics for larger ragfish were computed by D. Hankin and HSU fisheries

[2]INPFC. 1992. Scientific review of north Pacific high seas driftnet fisheries, Sidney B.C., June 11–14, 1991. Joint report by the National Sections of Canada, Japan, and the United States for a United Nations meeting hosted by Can., Dep. Fish Oceans, Inst. Ocean Sci., 86 p.

[3]McKinnell, S., Y. Watanabe, H. Nakano, H. Hatanaka, S. Ota, M. Dahlberg, L. Jones, S. Fitzgerald, W. Thogmartin, J. Wetherall, and P. Gould. 1992. Final report of observations of the Japanese high seas large-mesh driftnet fishery in the north Pacific Ocean 1990–1991. Joint Rep. Fish. Agency Jpn., Can. Dep. Fish. Oceans, U.S. Natl. Mar. Fish. Serv., NOAA, and U.S. Fish Wildl. Serv., 86 p.

[4]Yeh, S-Y, J. Sha, M. Dahlberg, L. Jones, S. Fitzgerald, J. Wetherall, and P. Gould. 1991. Final report of the 1990 observations of the Taiwanese high seas driftnet fisheries in the north Pacific Ocean. Joint Rep. Republic of China Council of Agric., U.S. Natl. Mar. Fish. Serv. and U.S. Fish Wildl. Serv., 83 p.

[5]Park, J. S., Y. Gong, Y. S. Kim, D. H. An, S. J. Hwang, M. Dahlberg, L. Jones, S. Fitzgerald, J. Wetherall, and P. Gould. 1991. Final Report. 1990 observations of the Korean high seas squid driftnet fishery in the north Pacific Ocean. Joint Rep.Republic Korea Natl. Fish. Res. Develop. Agency, U.S. Natl. Mar. Fish. Serv. and U.S. Fish Wildl. Serv., 75 p.

[6]Institution acronyms are identified in Table 1.

[7]Fitch, J. Marine Biologist, Calif. Dep. Fish Game, deceased.

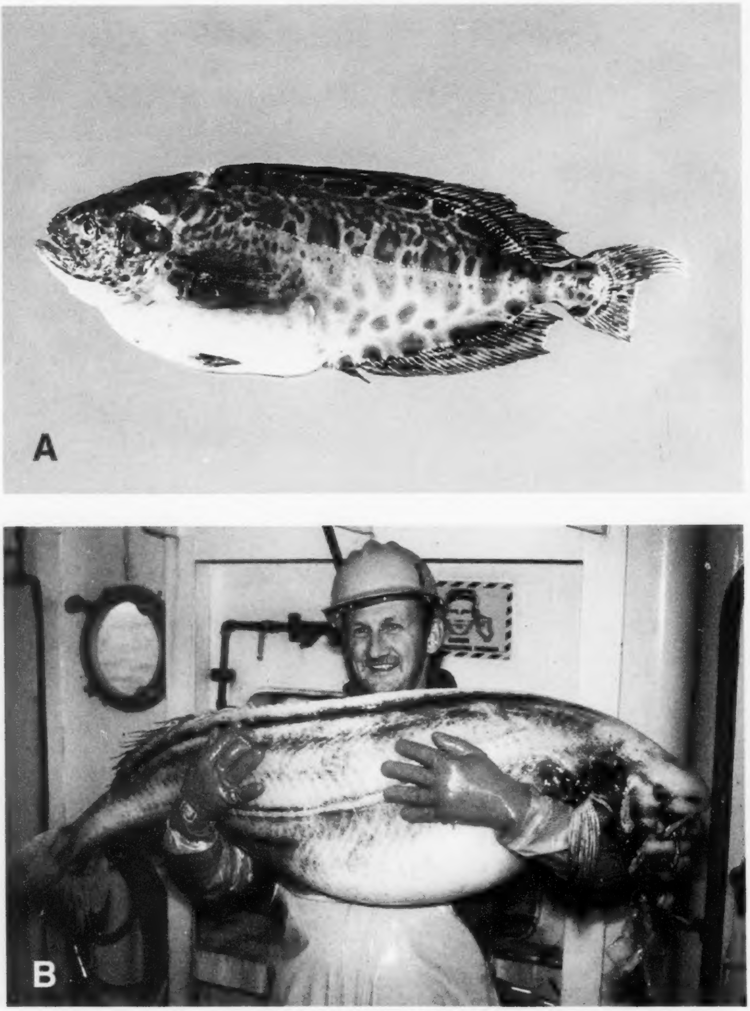

Figure 3A, B.—Shape and skin pattern of juvenile and adult ragfish, *Icosteus aenigmaticus* Lockington. A. Juvenile. SL 31 cm, wt. 0.42 kg, taken in purse seine fished in surface layer (0–8 fm) 2 mi. due west of entrance to Moss Landing, Monterey Bay, California by F/V *Junior*, Jimmy Campos, skipper, 22 July 1987 (Photo by Daniel Gotshall). B. Adult. Length unknown, wt. 35.8 kg, caught in groundfish trawl fished on bottom (479 fm) about 25–30 n.mi. west of Brookings, Oregon by R/V *Miller Freeman*, 4 November 1995. (Allen Harvison holding ragfish, photo by Robert Lauth, NOAA/NMFS/AFSC/RACE (acronyms defined in text)).

students.[8] Specimens measured (cm) for TL only in the field were converted to SL by the equation: SL = 2.57 + 0.87 TL (R = 0.98, n = 41) (Osborn[8]). Specimens without weights were estimated by least-squares regression (Zar, 1984) using males and females combined (Wt = 6.27g; SL = 2.7cm; R = 0.98, n = 30) (Bremm[8]). For fecundity studies, missing weights of large females used only females. Equations describing fecundity, egg maturation, and relative size of gonads are presented in results.

Written comments on whether eggs were flowing freely from the vent of adult female were not specifically recorded for some female specimens collected by HSU and CDFG. These records probably indicated no running ripe eggs. Some specimens were damaged in transit to HSU, and a few ovaries were ruptured or damaged during examinations made prior to delivery to HSU. For a few females, the ovaries were the only part of the fish deposited at HSU. Sufficient data were available on 14 females delivered to HSU to enlarge the estimates of fecundity. Standard gravimetric methods as described in Allen (1968) were used in estimating egg numbers. In a preliminary study, from 5 to 27 aliquot samples of eggs, depending upon the size of the ovary, were taken from predetermined positions along both ovaries. Three categories of egg size were noted in most ovaries. A study of the mean diameter of the "large-category" eggs (1.0–3.0 mm) in two specimens (HSU 7, 9) found no difference in aliquots taken from 19 to 25 positions along the length of the ovary. This confirmed a preliminary study that eggs were maturing at equal rates in all portions of the ovary (Allen, 1968). Subsequently aliquots were sampled from 5 to 9 positions only.

The gonads of one specimen (HSU No. 25, total gonad length 31.5 cm), appearing peculiar in gross external morphology, were studied histologically. The external formalized most-anterior section of the ovary was creamy white in appearance, a middle section purplish in color with some whitish underlying patches, and a posterior section was grayish in color with some purple tinge. A final narrow section of the gonad attaching to the vent presented a much more granular texture than the rest of the gonad. Gonad fixation was in 10% Formalin, dehydration and embedding used a tertiary butyl alcohol series, with staining by hematoxylin and eosin. Transverse sections 10 mm thick of tissue sampled from left and right positions along the length of the gonad were studied for any histological changes that

[8]Unpubl. term project reports, Tech. Writing, Fish. Dep., Humboldt State Univ., Arcata, Calif., Spring 1980, D. G. Hankin instructor: Osborn, W. M., Spawning characteristics of the brown ragfish *Icosteus aenigmaticus*, 20 p.; Sands, R. S., Sex differences, fecundity and spawning of the brown ragfish, *Icosteus aenigmaticus*, 14 p.; and Bremm, D., Size, fecundity, and spawning characteristics of the brown ragfish, *Icosteus aenigmaticus*, 19 p.

Table 2.—Number of ragfish by sex recorded yearly from 1948 through 1977 by HSU and by other institutions (OI) surveyed by letter August 1976.[1]

Year	Female HSU	Female OI	Male HSU	Male OI	Sex unknown HSU	Sex unknown OI	Totals HSU	Totals OI	HSU and OI combined
1948						1	0	1	1
1952						6	0	6	6
1953						2	0	2	2
1954		2				1	0	3	3
1958	1					3	1	3	4
1960	1						1	0	1
1961	1	1				1	1	2	3
1962		2	2			2	2	4	6
1963	1	1		1		2	1	4	5
1964						1	0	1	1
1965		1					0	1	1
1966						1	0	1	1
1967	1					1	1	1	2
1968	1						1	0	1
1969	2	1				1	2	2	4
1970	1	2				6	1	8	9
1971	1						1	0	1
1972	2						2	0	2
1973	1		1				2	0	2
1974		2	1	1			1	3	4
1975			1			4	1	4	5
1976	3	2					3	2	5
1977	4	1		1		1	4	3	7
Total	20	15	5	3	0	33	25	51	76

[1] Additional historical data uncovered in 1990 and 2000 not included (see footnotes in Table 1).

might have indicated incipient hermaphrodism in the specimen.

Ragfish Capture Gear

Many types of fishing gear have taken ragfish in the historic record. Not only is this information inherently interesting, but it can be of practical value when planning future ragfish studies. Knowing which depths and bottom substrates have been sampled by various gear can direct future research toward unsampled areas (Allen et al., 1961).

Hand Collections

The most unique acquisitions of ragfish arise from hand collections involving chance encounters with moribund or dead ragfish either washed up on beaches or stranded in adjacent shallow waters. Ragfishes used by ichthyologists initially describing the species were all from chance hand collections (Lockington, 1880: 3 specimens found on a fishmonger's display table in San Francisco in 1885; Bean, 1887: an adult from a beach at Damon, Wash., collected by Charles Willoughy, Indian agent). Another early specimen was hand collected by J. O. Snyder in 1906 from a beach at Pacific Grove, Calif. (6 cm fish, USNM 75159). Craig Carrothers, an HSU student, found a 9 cm SL juvenile in shallow water at the foot of a boat ramp located north of the north jetty entrance to Humboldt Bay, Calif.[9] A surprisingly large number of adults have been hand collected from the beaches of bays and inlets of southeastern Alaska (6 records furnished by Bracken[10] and Wing[11]). Other recoveries from beaches in southeastern Alaska were made by school children on field trips and by young boys on fishing trips near Kake and Petersburg, Alaska (Marsh, 1995; Kondro[12]). Marsh reproduced in his magazine article a photograph of one of these specimens being displayed by its captors.

Probably the most interesting example of a hand collection was that of a specimen taken from a Steller sea lion, *Eumetopias jubata*, in surface water by a sport fisherman at Outer Point near Auke Bay and about 3 mi. northwest of Juneau, Alaska, 9 May 2000 (Wing[13]). The fisherman was attracted by a surface disturbance caused by the sea lion and was able to collect the posterior trunk and tail of the ragfish. The remains (= 150 cm TL) were given to K Koski for delivery to ABL for identification.

[9]HSU 1831; June 12, 1983.

[10]Bracken, B. E. 1999. Alaska Dep. Fish Game, Petersburg, Alaska. Personal commun.: Letter and phone.

[11]Wing, B. L. 1999. Auke Bay Laboratory, Natl. Mar. Fish. Serv., NOAA, Juneau, Alaska. Personal commun.: Letter, and phone.

[12]Kondro, L. B. 1995. Kake, Alaska. Personal commun.: Letter to B. L. Wing, 1999 phone call to G. H. Allen.

Trawls

Many different trawls have taken ragfish: commercial bottom (otter) trawls, shrimp trawls of several designs, beam trawls, and midwater trawls. Historically, the largest number of ragfish records have come from adults taken by otter trawls used in a commercial fishery on the continental shelf between Camp Mendocino and Pt. St. George, northern California. Bracken[10] and Wing[13] recorded ragfish captures from inside waters of southeastern Alaska by both shrimp and beam trawls. A modified North Atlantic capelin net took an adult ragfish (130 cm) when fishing at 75 fm (137 m) over a bottom depth of about 300 fm (549 m) in the lower end of Chatham Strait, southeastern Alaska, in late June 1976 (Bracken[10]). Midwater trawling by Canadian researchers has incidentally taken ragfish (Peden, 1974). Two adults (80 and 90 cm, BCPM 972-62) came from a station 70–80 mi. west of Cape Flattery, Wash., while a third fish (BCPM 80-120, size unknown) was caught near the Cobb Seamount off Washington's northwest coast.

The commercial bottom and pelagic trawl fisheries off the west coast of the United States, contributing most of the ragfish documented in the historic records, also were the source of many ragfish recorded in the NMFS observer program (Table 3, geographic Area B). It was not feasible to describe all the types of trawls used in these fisheries. NMFS research surveys of these same fisheries took many ragfish primarily using bottom trawls fished both in the water column and near the ocean bottom.

Gillnets

The earliest gillnet caught ragfish were recorded from southern California (Fitch and Lavenberg, 1968). Wing[11] recorded four gillnet caught ragfish from south-

[13]Wing, B. L. 2000. Auke Bay Laboratory, Natl. Mar. Fish. Serv., NOAA, Juneau, Alaska. Personal commun.: Letter, phone, or e-mail.

Table 3.—Number of ragfish recorded from commercial fisheries harvest investigations[1] by areas[2] from 1976 to 1999 by the NMFS Auke Bay Laboratory, Juneau, Alaska, 1976–99.

	Fishery surveys (RACE)			Fishery observers (REFM)			RACE and REFM combined		
Year	A	B	C	A	B	C	A	B	C
1976	2	1	1				2	1	1
1977	1	1	1				1	1	1
1978	1						1		
1979	10						10		
1980	7	5	2				7	5	2
1981	13						13		
1982	19						19		
1983	4						4		
1984	1	1					1	1	
1985	12						12		
1986	3						3		
1987				1			1		
1988							0		
1989	2	1		5			7	1	
1990	1	1	1	92			93	1	1
1991				80	5	5	80	5	5
1992	2	2		92	53	1	94	55	1
1993	8	8	2	45			53	8	2
1994				67			67		
1995	3	3	2	35	8	3	38	11	5
1996	1	1		21	3		22	4	
1997				15	2		15	2	
1998	1	1		44	12		45	13	
1999[1]				32			32		
Total	91	25	9	529	83	9	620	108	18

[1] Databases: 1) Survey program of the Resource Management and Conservation Engineering Division (RACE) (n=91), and 2) Fishery Observer program of the Resource Ecology and Fisheries Management Service (REFM) (n=529).

[2] Geographic Areas: A = eastern North Pacfic Ocean, Gulf of Alaska, and North America continental shelf combined; B = North American continental shelf south of lat. 48°N; and C = Continental shelf off Oregon and California (south of lat. 43.5°N).

eastern Alaska waters. Canadian research studies associated with the North Pacific salmon fisheries took nine ragfish in gillnets (Larkins, 1964). A. E. Peden[14] listed a juvenile fish taken in a surface gillnet on 28 August 1970, 85 mi. northeast of Attu Island in the Bering Sea. As noted earlier, at least 27 ragfish were identified while sampling the high-seas commercial catches of salmon gillnet fisheries in 1990 under international monitoring programs, as detailed later in section on ragfish distribution in the North Pacific Ocean.

Seines

Seines operated from vessels or fished from beaches have also caught ragfish. Higgins (1921) noted a specimen of ragfish as being taken in a "mackerel net" off San Pedro, Calif., presumably a seine of some sort. A purse seine set near Weaver Bay, Queen Charlotte Islands, B.C., took a juvenile ragfish (Pritchard, 1929) which probably was the specimen used to illustrate a juvenile pictured in Clemens and Wilby (1961:Fig. 248). If the "commercial salmon seine" that Schultz (1930) reported to have taken a ragfish (size not available) (near the mouth of the Columbia River at Ilwaco 12 August 1926), actually was a beach seine operated from shore, this would be another type of sampling gear taking ragfish. Purse seine fisheries off central and southern California have taken "fair numbers" of ragfish (Fitch and Lavenberg, 1968), probably as associated with the large historical fishing effort for sardines (e.g. one specimen recorded in 1927: HMCZ 34915). In July 1962, a purse seine captured a juvenile ragfish (27 cm SL) 25 n.mi. northeast east of San Clemente Island, southern California (SIO 062-385). Wing[11] reported a unique catch of a ragfish in shallow water (7 m) with a commercial purse seine fishing for salmon in Amalga Harbor located 24 mi. north of Juneau, Alaska, at the head of Chatham Strait. The specimen was estimated to be about "six-feet (183 cm) long" and was stored for future study.

[14]Peden, A. E. 1976. Mar. Biol. Div., B.C. Prov. Mus., Vancouver. Personal commun.: Letter to R. Behrstock.

Whale and Fish Stomachs

Clemens and Wilby (1949) noted several authors reporting sperm whale, *Physeter catodon*, stomachs as a source of ragfish specimens; with the 1937 record of a ragfish head from a sperm whale taken 30–50 n.mi. northwest of Rose Harbor, Queen Charlotte Islands, B.C. (FMNH 35,590) most frequently cited. Fish stomachs also provide ragfish records, such as the 16 cm SL specimen found in a tuna (species and length unspecified) taken in June 1970, 85 mi. northwest of the Columbia River mouth (Stein[15]).

Traps

Stationary fixed gear such as traps have also taken ragfish. Movable box-shaped traps used for sablefish, *Anoplopoma fimbria* Pallas, caught ragfish (specimen size and sex not listed) in Barkley Sound, B.C. from 265 fm (485 m) depth (Cowan, 1938). Stationary traps with a panel (lead) attached to shore used in early commercial salmon fisheries have also taken ragfish. Crawford (1927) lists a female about 6 ft long (183 cm) caught at Whidby Island, Wash. on 15 September 1925, as well as noting another ragfish reported from a trap operated at Gig Harbor, Wash., in 1913 or 1914. The largest recorded specimen (208 cm TL) found in the literature came from a stationary salmon trap at Sooke, B.C. (Cowan, 1938). The first records in English known to the author of ragfish off the Pacific coast of Japan were from trap catches (Abe, 1954, 1963).

Hook and Line

Hook-and-line gear used by anglers have regularly sampled ragfish from shallow waters along the west coast of North America. An adult taken from a breakwater at Monterey Bay, Calif., was previously mentioned (Bolin, 1940). Two small boys fishing from a breakwater at Victoria, B.C., in July 1936, took an adult that appeared to be larger than the biggest ragfish yet officially recorded (208 cm TL) (Cowan, 1938). A 25 cm SL ragfish (UCLA W-53-245) was caught by hook and line fishing from a boat on 17 May 1953, in shallow water off San Onofre, Calif. (Fitch, 1953). Fishery biologist D. Bevan took a juvenile ragfish while

[15]Stein, D. 1976. Oreg. State Univ., Corvallis. Personal commun.: Letter to R. Behrstock.

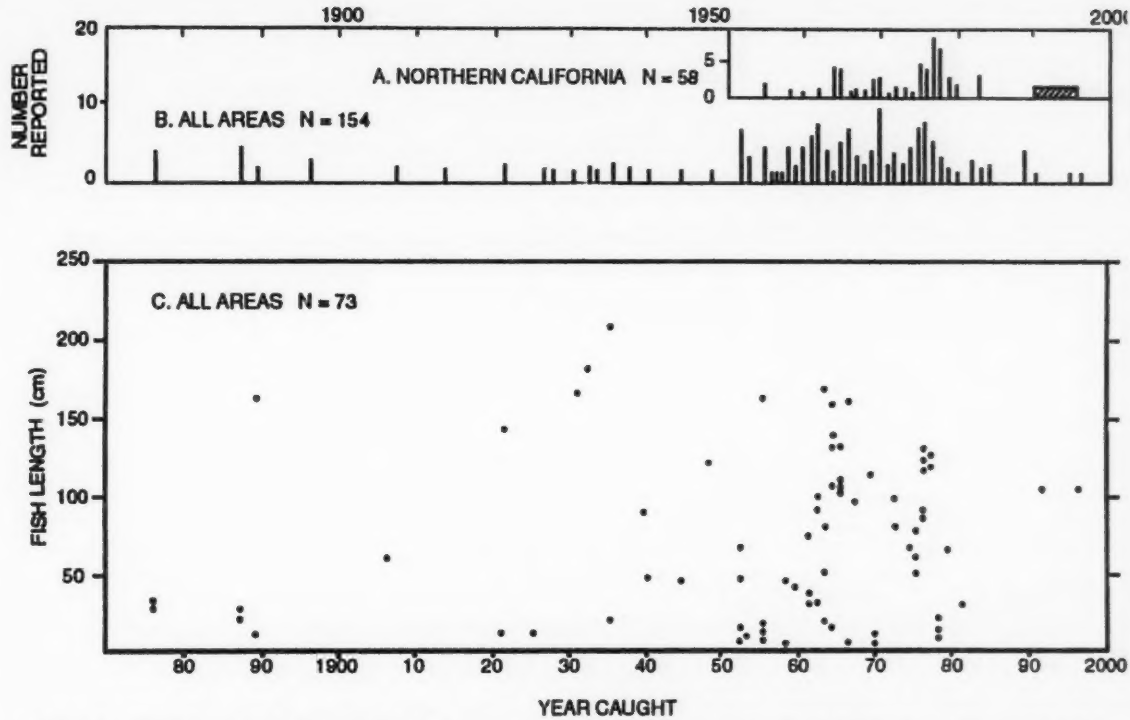

Figure 4.—Number and length (cm) of ragfish >5 cm recorded historically from eastern North Pacific Ocean (Commercial high-seas gill net fisheries and NMFS data excluded). Legend: A = number of ragfish recovered from bottom trawl fishery off northern California–southern Oregon (1990–95 recoveries estimated, and no recoveries for 1996–98). B = number of ragfish recorded from all sources (eastern North Pacific Ocean, Gulf of Alaska, Alaska peninsula). C = length (cm) of ragfish available from records noted in Part B above.

fishing in 110 fm (201 m) 8.5 n.mi. south southwest of Kruzof Island, Alaska, on 13 Sept. 1958.

Gear Not Represented

From a technical fish sampling viewpoint, I found it surprising that there were no records of ragfish taken by salmon trolling gear in northern California waters. D. Bitts[16], a troll fisherman, could not recall that he or other trollers ever caught a ragfish. Similarly, no records in the literature were found of ragfish being caught on longline fishing gear used for Pacific halibut, *Hippoglossus stenolepis* Schmidt, or sablefish. Future reviews of research and management agency files on troll and longline fisheries should be made, since these gears fish areas not readily sampled by other gear types (rocky reefs and headlands).

[16]Bitts, D. 1999. N. Calif. Troll Fisherman's Assoc., Eureka, Calif. Personal commun.

Ragfish Distribution

A history of ragfish range extensions is presented geographically beginning in California and proceeding counterclockwise around the North Pacific. This analysis primarily uses historical literature and is supplemented where appropriate with records from previously mentioned NMFS databases.

On average, about one specimen per year has been recorded historically by ichthyologists over the past 125 years from ragfish caught in the eastern North Pacific Ocean (Fig. 4B). Bolin (1940: 287) commented on the early accession rate of ragfish as follows: "This rare visitor, which on the basis of meager available records appears to be taken about once every 20 years from the waters of the state, is stated by Schultz and DeLacy (1936) to be not rare in the Pacific Northwest although I have been able to find only eleven definite records of its previous capture." Schultz and DeLacy's contention proved correct. The rate of accession of ragfish specimens increased dramatically after the end of World War II (Fig. 4B).

The southern end of the now known ragfish range provided the juvenile specimens taken off San Francisco that were used for the species' original description (Lockington, 1880). Range extensions that were recorded from 1875 to the turn of the 20th century, as reported by Jordan and Everman (1898), came from the capture of ten additional juveniles (about 25 cm length) that were known from "Deep water off California, Oregon, and Washington; the example before us from Monterey" (Fig. 4C). Southward extensions of the range extended to San Pedro (Higgins, 1921), to Monterey

(Thompson, 1921), to Cortes Bank 100 n.mi. off San Diego (Fitch, 1953), and of larval ragfish to lat. 30.5°N off northern Baja California, Mexico (Moser et al., 1994). Northward extensions were reported by Schultz (1930) to the mouth of the Columbia River; by Pritchard (1929) to inside waters of the Queen Charlotte Island, B.C., Canada; by Schultz et al. (1932) to inside waters near Petersburg, Alaska; by Schultz and DeLacy (1935–36) to southern Puget Sound; and by Cowan (1938) to the Strait of Juan de Fuca.

NMFS catch records came from two separate programs that studied U.S. commercial fisheries extending from the Bering Sea to southern California (Table 3). The Commercial Fishery Observer program of the NMFS Alaska Fisheries Science Center, Seattle, Wash., placed personnel on commercial fishing vessels beginning in 1987 to sample the catch of walleye pollock, *Theragra chalcogramma* (Resource Ecology and Fisheries Management program (REFM)). The first ragfish reported by an observer in 1987 was caught by a bottom trawl fished southwest of the entrance to Yakutat Bay, Gulf of Alaska, off the edge of the continental shelf at 192 m (105 fm). From 1987 to mid 1999, the observer program logged 529 ragfish. A second program by the NMFS that has recorded ragfish catches was a scientific survey of bottom fishes conducted by trawling (Resource Management and Conservation Engineering (RACE)). Two ragfish were logged in 1976 from bottom trawls conducted off central California, with the last ragfish reported caught in 1998. Survey trawling recovered 91 ragfish total. Only 18 ragfish recorded in the two studies were taken from California waters (Table 3, geographic area C).

Data Limitations

Inconsistency and incompleteness of information available on adult ragfish, other than the CDFG and HSU collections, circumscribed the analysis that could be performed with the data. Degree of completeness of the ragfish data was defined by the presence of six desired metrics: 1) date: often only the year of capture was listed; 2) location: often only a general geographic area of recovery was listed; 3) depth of water where fish were recovered: precise depths could be estimated when latitude and longitude at the beginning and ending of hauls were given, but often records only listed a single depth; 4) length: often not standardized; 5) weight: mostly in pounds; and 6) sex: often reported with equivocation. For 52 specimens in the HSU and CDFG records, the percentages of completeness within the six categories were: 98, 49, 70, 85, 42, and 63, respectively. Least complete were location of capture (49% complete) and weight (42% complete). For individual specimens, only 21% had data on all six categories, while 14% of the specimens had only data on three or fewer of the categories. Data on ragfish accessed from institutions other than HSU or CDFG were much less complete. This varied from 4% of the specimens having only information listed for only one of the six categories, to only 4% with information on five or six categories. Consequently, data on ragfish recorded by CDFG and HSU was most useful for biological studies, with the remaining data mainly utilized for subjective studies of distribution and historical occurrences.

The commercial fishery observers (REFM) listed date of trawl, trawl number, year, gear (mostly pelagic trawl with a few bottom trawls listed), latitude and longitude of the trawl location, depth in meters at which the gear was fished, and the depth of the ocean floor at the trawl location. NMFS scientific surveys (RACE) employed bottom trawls as their standard sampling gear, with some hauls also made off the bottom. Of the 91 specimens listed, 83 were weighed (kg), and 5 specimens were measured for length (mm). Surface water temperatures at trawl locations were listed for most hauls, while for 52 hauls the temperature was recorded at the depth at which the gear was fished. Most hauls in the RACE data bank showed a single specimen for each trawl, but 11 hauls listed from 2 to 6 ragfish in the catch. Total weight only was listed for ragfish observed in each haul, thus only mean weight could be reported for hauls listing more than a single ragfish.

Range extensions into the western and central North Pacific Ocean came from specimens found by fisheries agencies during increased monitoring and research of commercial fisheries. Off Japan, Abe (1954) described the first record of a ragfish (a 26 cm juvenile), followed by an extension of ragfishes to roughly 400 n.mi. east-southeast of the southern tip of the Kamtchatka Peninsula by a recovery of 7 specimens (48–75 cm) from a Japanese high-seas gillnet fishery (Kobayashi and Ueno, 1956).

Range extensions also occurred into the eastern North Pacific from an incidental catch of nine ragfish by U.S. Bureau of Fisheries research vessels from 1955 to 1961 (Larkins, 1964). The ragfish came from widely scattered points (southern Bering Sea, North Pacific Ocean bordering the Aleutian Islands, and in northern and southern portions of the Gulf of Alaska). No catches came from the northern portions of the Bering Sea or in the eastern North Pacific Ocean south of lat. 50°N.

The first eastern North Pacific Ocean specimens were found by research trawling 72 n.mi. due west of Cape Flattery, Wash. (Peden, 1974). More recent incidental catches of ragfish in commercial high-seas salmon fisheries were reported in 1991 and 1992. These records came from western North Pacific Japanese, Korean, and Taiwanese gillnet fisheries for salmon and squid that were being monitored owing to concern about incidental catches of marine mammals, seabirds, and marine turtles (McKinnell et al.[3], Yeh et al.[4], Park et al.[5]). These reports listed ragfish as "unidentified ragfish/medusafish," ragfish only, or separately as ragfish and medusafish, *Icichthys lockingtoni*. On first glance, medusafish superficially appear like juvenile ragfish (Goode and Beane, 1895, Plates LXI, LXII), and thus would be a source of confusion among partially trained personnel sampling the catches of the commercial fishing vessels.

Months of recoveries in these 1990–91 high-seas fisheries were: March-Japanese, 4 unidentified ragfish/medusafish; September-Korean, 8 ragfish and 50 medusafish; and no month-Taiwanese, 15 ragfish. The most southerly operations of these fleets were Japanese, lat. 26°N, long. 180°; Korean, lat. 40°N, long.178°W; and Taiwanese, lat. 35°N,

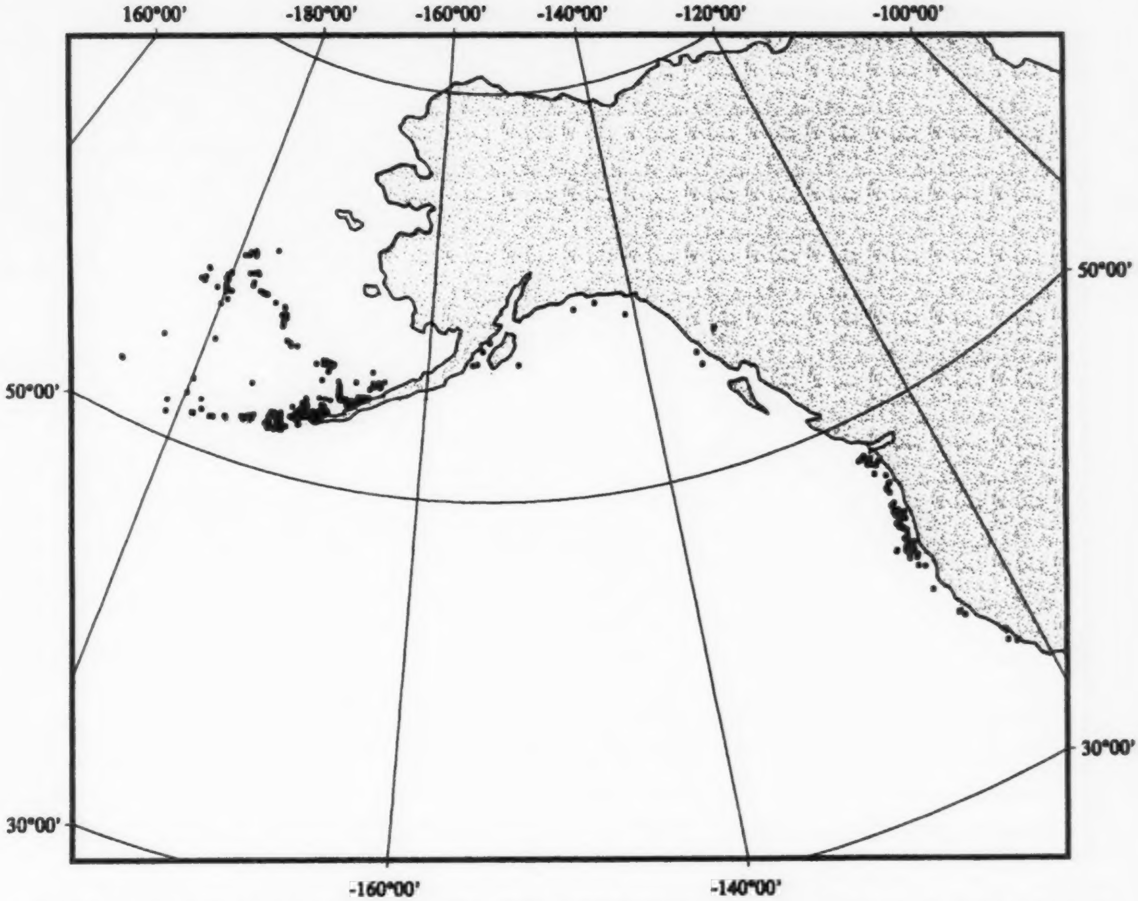

Figure 5.—Distribution of ragfish (n=620) recovered by NMFS RACE and REFM combined fishery observer and survey programs from commercial trawl fisheries and research trawling, eastern North Pacific Ocean, Gulf of Alaska, and Bering Sea, 1976–99. (Figure provided by Nancy Maloney and John Heifetz, NMFS Auke Bay Laboratory, Juneau, Alaska.)

long. 178°W. Field notes and voucher photographs of specimens could not be consulted for this paper to precisely locate the most southerly point of recoveries. I suggest, however, that in the future, ragfish might be found as far south as the Kinmei Seamount (lat. 35°N, long. 172°E) which rises to about 20 fm (37 m) below the ocean surface.

Knowledge of ragfish distribution in the North Pacific Ocean was dramatically expanded with the recovery of specimens associated with the monitoring of commercial fisheries in the eastern Pacific Ocean and the Bering Sea by NMFS. Ragfish catch locations reported in the RACE and REFM programs ranged from Pt. Lopez, central California coast, to the central Bering Sea, with large numbers of ragfish reported caught just north of the central Aleutian Islands (Fig. 5). To reduce ragfish recovery patterns possibly biased by the commercial fishery concentrating on walleye pollock, the recoveries made by the research fishing (RACE) were plotted separately (Fig. 6). In both plots there is a striking pattern of recoveries roughly along the 100 fm contour separating Bristol Bay to the east from the deep waters of the Bering Sea to the west.

A pattern of recoveries beginning at Unimak Pass in the eastern Aleutian Islands stretching northwest along the 100 fm (200 m) contour ended in the north central Bering Sea just beyond lat. 60° N. The waters to the east of the 100 fm contour are relatively shallow (<100 fm). To the west, however, the ocean floor drops steeply to over 1,000 fm (1,830 m). The most northward cluster of ragfish catches along this drop-off was beyond lat. 60°N and approaching long. 180°. Marine charts available to me indicated the possibility of a relic drainage depression providing a gentle transition from the very shallow water of the Bering Strait to the north and the deepwater basins of the Bering Sea to the south. This area of transition lies roughly 140 n.mi. southeast of Cape

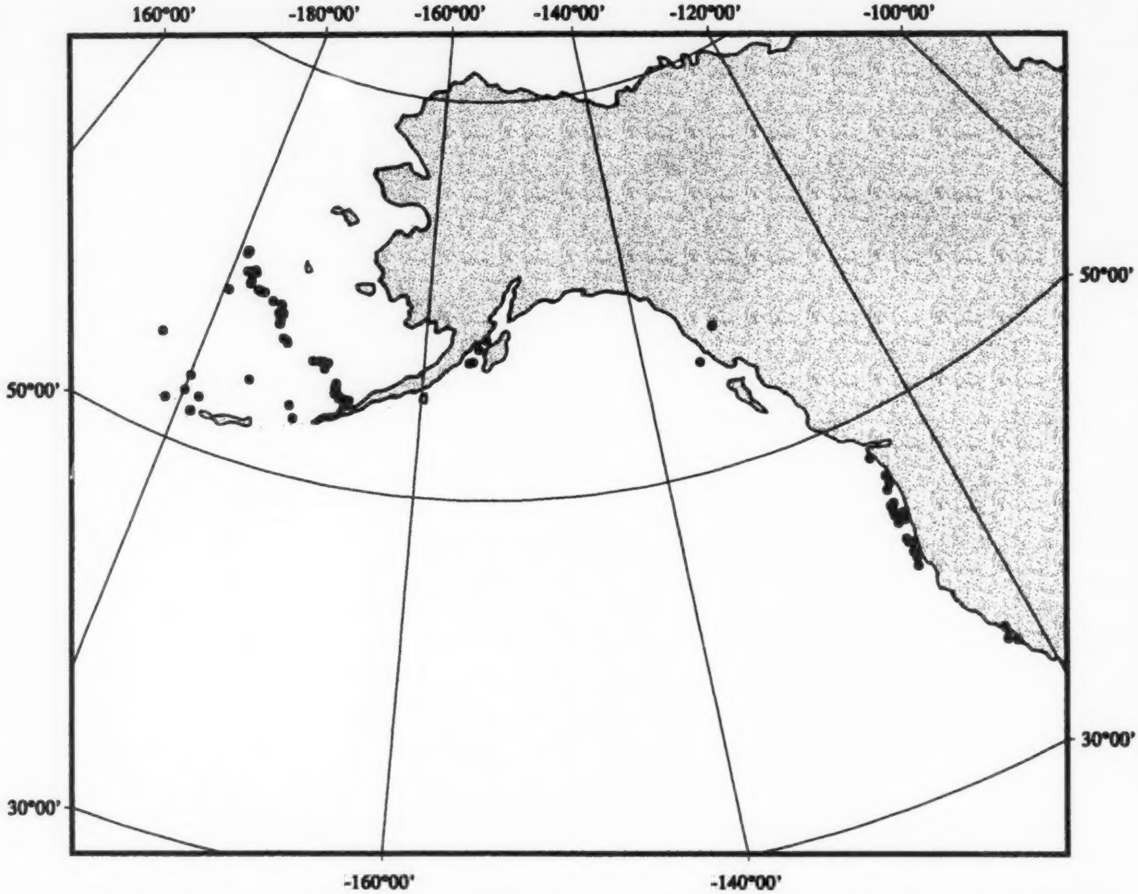

Figure 6.—Distribution of ragfish (n=91) recovered by NMFS RACE fishery surveys, eastern North Pacific Ocean, Gulf of Alaska, and Bering Sea, 1976–99. (Figure provided by Nancy Maloney and John Heifetz, NMFS Auke Bay Laboratory, Juneau, Alaska.)

Navarin, Siberia, and about 150 n.mi. west of the south end of St. Matthews Island. The bottom is listed as primarily gray mud interspersed with a mixture of sand and shell. The gear depth listed for these northernmost trawls were shallow and virtually the same as listed for water depth (40–80 fm or 73–146 m range).

Precise analysis of the location and depth of all trawls in the NMFS data banks needs to be undertaken to expand this cursory use of the NMFS data to delineate ragfish distribution and habitats. Ragfish distribution records are lacking for the continental shelf off British Columbia, Can. This is probably due to the research surveys only sampling surface waters (Taylor, 1967a, b: 100 fm or 183 m). Canadian agencies managing commercial bottom trawl fisheries were not contacted for possible records in this study.

Early and Juvenile Life History

Ragfish early life history (ELH) stages for the eastern North Pacific Ocean have only been collected and described since the end of World War II when resources became available to study the ocean environment associated with major commercial fisheries in the California current (Matarese et al., 1984, 1989; Moser et al., 1993,1994). A distinctive external morphology was described for ragfish eggs by Watson (1996:1201) as follows: The "ragfish eggs are readily distinguished from all others by chorion and oil globule diameter, and in late stages by the embryonic pigmentation" (Fig. 7).

Eggs and larvae of ragfish off California were in low abundance throughout the range of the sampling program, with the greatest density (mean number for all tows of 0.10–0.13 eggs/10 m^2 lying between San Francisco Bay and Point Conception (Moser et al., 1994: 86). Most ragfish eggs and juveniles in this area were taken in March and were concentrated at two distinct distances offshore (10–20 and 50–200 n.mi.) (Fig. 8) (Moser et al., 1994:86). Sampling was

relatively sparse in northern California waters.

An extensive study in May 1990 of early life history of marine fishes in the eastern North Pacific Ocean off southeastern Alaska was conducted by the NMFS (Wing and Kamikawa, 1995; Wing et al., 1997). The area surveyed was covered by eight transects ranging from lat. 58°N, long. 140° W southeastward to lat. 54°30N, long. 136° W (Cross Sound to Dixon Entrance) and varied from about 200 n.mi. by 100 n.mi. in width. Neuston was sampled using 50 × 30 cm Sameoto neuston net equipped with a 0.505 mm mesh net and a plastic cod end. A total of 86 tows, each 1 n.mi. in distance, sampled the top 51 cm of the water column at 67 stations.

No ragfish larvae were noted in the catches, although, at the 56 stations where fish eggs were recovered, ragfish eggs were third most abundant. Very few ragfish eggs occurred in tows made inside the 200 m (37 fm) depth contour, except for a station located at the southern entrance to Chatham Strait (Wing et al., 1997:Sta. 4a, Fig. 1, 4). The study also sampled the water column for ichthyoplankton by oblique tows with a 60 cm diameter bongo net array fitted with two 505 mm mesh nets and cod ends. Maximum sampling depth targeted was 300 m but varied according to bottom depth and contour over shallower waters. Ragfish eggs were the second most abundant fish eggs collected (Wing et al., 1997: Table 3). Surprisingly, no ragfish larvae were identified among the 100 taxa and suspected species listed from these same samples (Wing et al., 1997: Tables 2, 3). Most of the ragfish eggs were found in tows made beyond the 200 m (100 fm) contour, and they were most abundant in the southern half of the study area (entrance to Chatham Strait to the north edge of Dixon Entrance).

Central California and southeastern Alaska ragfish eggs and larvae have some similarities in their local distribution patterns. Eggs and larvae were scarce to absent in shallow nearshore waters. The overall abundance within each study was near or adjacent to submarine canyons (Monterey Canyon, Calif.), and in the deeper waters of the entrances to large inlets and bays (southeastern Alaska).

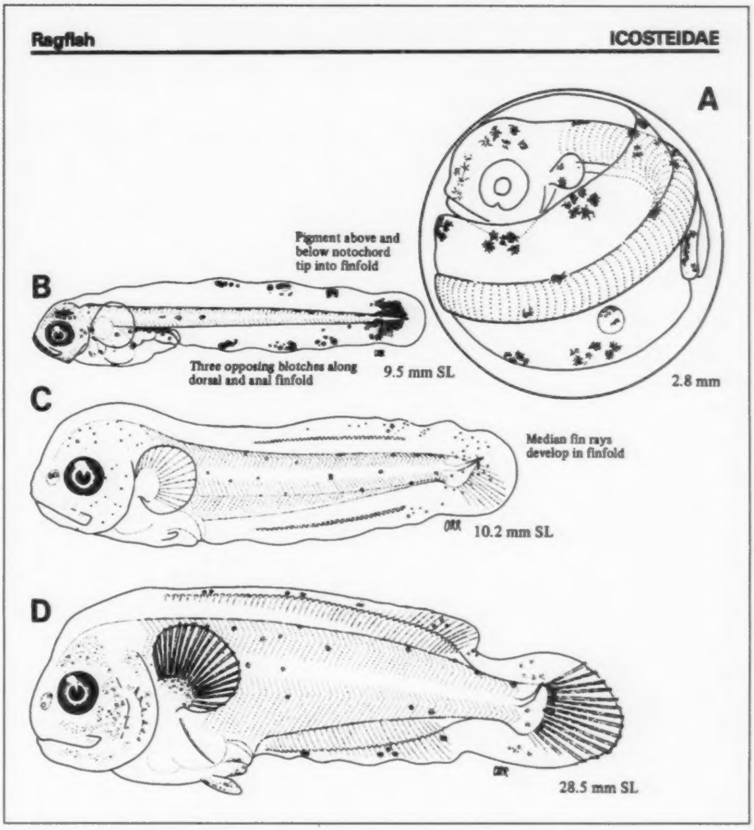

Figure 7.—Illustrations of ragfish egg and larvae from Matarese et al., 1984.

Also, the sampling gear in both areas failed to take larger larvae (roughly >3 cm TL).

Several authors have commented on the lack of knowledge on ragfish between the ELH stages in the sampling and the subsequent appearance of larger juveniles (Matarese et al., 1984). Historical records provided little data on ragfish ranging between 5 and 50 cm range (Fig. 9). Depth of capture of smaller specimens was uncertain or rarely recorded (unknown: 6, 7, 16, 20, 20, 28, 38, 52 cm; shallow, 1 fish 25 fm and 1 fish 50–450 fm). Smaller juveniles had a slight tendency to be caught nearer to shore than larger juveniles (Table 4), with catch locations varying between the surf zone and 14 n.mi. off the coast. Smaller ragfish reported in other regions around the North Pacific Ocean include a juvenile of unknown length taken in a surface gill net 85 n.mi. northeast of Attu Island in the Bering Sea, and a 38 cm fish from the Gulf of Alaska about 200 n.mi. southwest of the entrance to Cross Sound (ABL: AB 61–38; lat. 57°N, long. 141°W), and a 48 cm specimen (UW 8385) from the north Pacific (no specific location). The last ragfish to enter the HSU records was a small spotted juvenile estimated at 33 cm (13 in) length by a fisherman who did not wish to donate the specimen because it held aesthetic appeal to him. The fish was captured on 3 August 1999 in one of three midwater trawls made at 100–135 fm (183–247 m) depths while fishing on a north to south track over the 500 fm (915 m) contour about 15 n.mi. west of Redding Rock off northern California. Historically, there were two other juve-

Ragfish **_Icosteus aenigmaticus_**

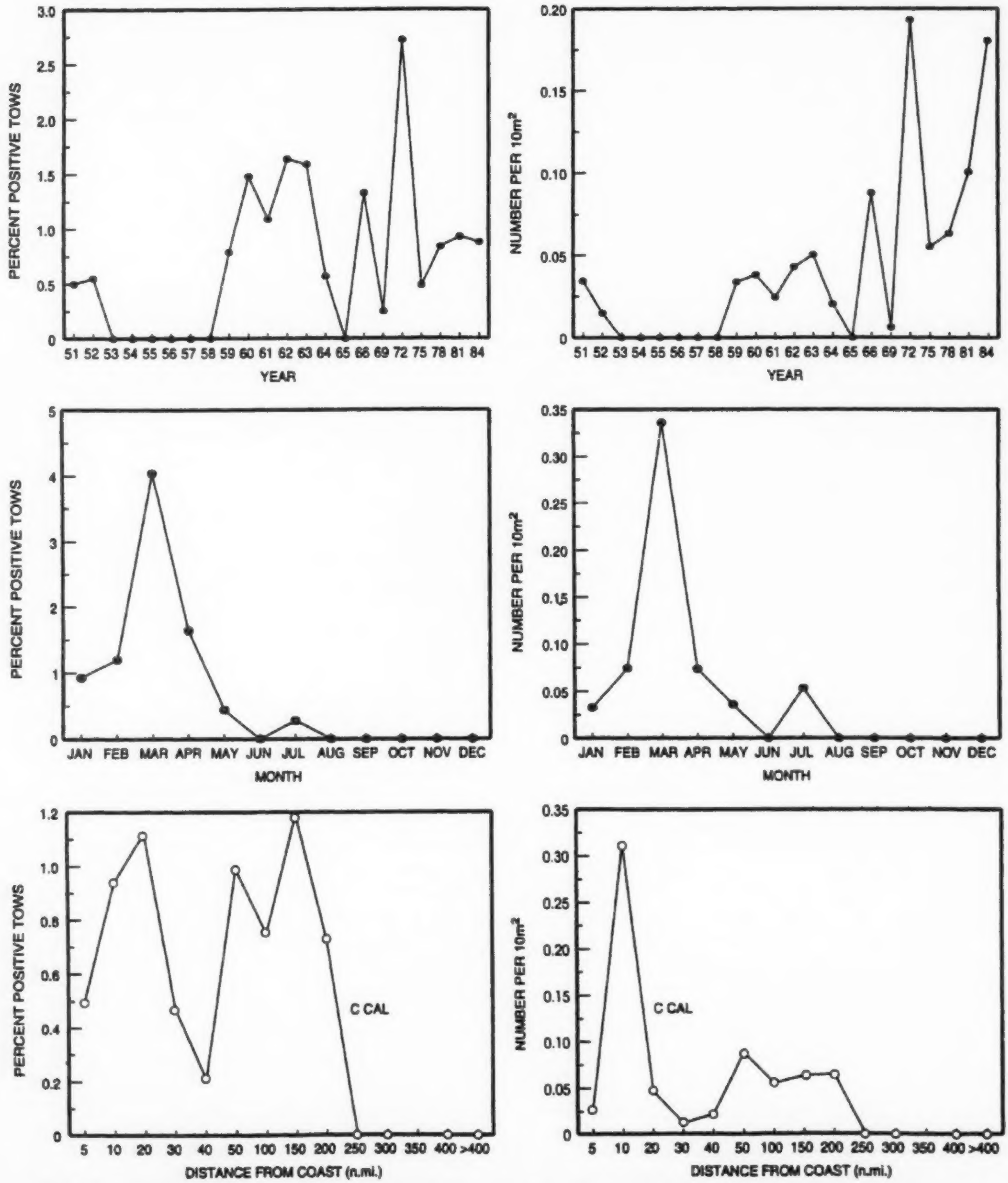

Figure 8.—Abundance by year, month, and distance from coast of ragfish egg and larvae sampled from the California current region (from Moser, et al., 1994).

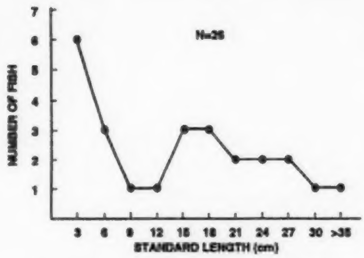

Figure 9.—Length-frequency of juvenile ragfish <35 cm SL from records of ichthyological collection (Table 1) of specimens recorded from North Pacific Ocean, 1875–1977.

niles, one of 19 cm, also recorded from this area (Table 4).

Of 53 ragfish reported off the central and northern coasts of Japan (Kubota and Uyeno, 1971: Tables 1, 2) most were juveniles between 25 and 33 cm SL, except the smallest specimen of 15 cm SL taken by a trap net set for *Seriola* sp. and *Trachurus* sp. off Manazura, Sagami Bay, central Japan (Abe, 1954). Most of these specimens were in or destined for the fish markets and were caught relatively close to shore where deep water occurred. The shallow nearshore place of capture of the 31 cm SL juvenile in Figure 3A is consistent with conditions of capture for other California juveniles recorded, and especially with the catch location of Japanese juvenile ragfish.

Smaller juveniles (5–20 cm TL) were taken in a program of studying ichthyoplankton off Oregon conducted over a 20-year period by Oregon State University's Department of Oceanography (Table 5). Collections were made with midwater trawls fished obliquely or through surface waters. There were 21 juvenile ragfish caught ranging from 1.5 to 16.5 cm TL (Table 5). Ragfish juveniles were sampled primarily from surface waters extending 19–85 n.mi. off the coast. In 7 tows the nets were fished only from 50 fm (92 m) to the surface, in 2 hauls the nets were sampled in a 100–150 fm (183–274 m) range, and two other samplings began at a 500–600 fm (942–1,098 m) range. Even though there is uncertainty from having specimens caught at any depth during lowering and retrieving the trawls, the small, immature ragfish appeared to be distributed randomly throughout the sampled area.

Of the 22 smaller ragfish (<1.1 kg) from continental shelf research reported in the NMFS (RACE) database (Table 6), most only had weight listed, with only 7 specimens also measured for length (cm). Of these, 5 were juveniles taken off the coasts of Oregon and Washington (Fig. 10), at depths of capture comparable to that found for all smaller ragfish recorded in the database (Fig. 11). Although the smaller ragfish (<0.1 kg) were in the shallowest water (<150 fm or 274 m), slightly larger ragfish (0.3–0.5 kg) were

Table 6.—Weight of ragfish caught by NMFS research (RACE) during trawling along the continental shelf of the eastern North Pacific Ocean and in the Bering Sea, 1976–98.

Range in weight (kg)	No. of specimens: Continental Shelf (Lat. 36°N–Lat. 48°N)	Bering Sea (Lat. 51°N–Lat.60.2°N)	Combined
<0.1	4		4
>0.1–1.0	13	2	15
>1.0–5.0	2	1	3
5–10		11	11
10–15		11	11
15–20		10	10
20–25	1	7	8
25–30	1	11	12
30–35		2	2
35–40	1	1	2
40–45		1	1
Totals	22	57	79

Table 7.—Weight of ragfish by depth of trawls caught by NMFS research (RACE), eastern North Pacific Ocean, 1976–98.

Weight (kg)	Depth of trawls (fm): No.	Min.	Mean	Max.
<1.1	23	38	244	623
3.5–7.5	6	211	340	601
8–15	19	30	299	495
15–25	19	147	263	425
25–37	18	115	301	435
Combined	85	30	289	623

Table 4.—Size, depth, and distance from coast of small juvenile ragfish (5–50 cm range) caught over U.S. continental shelf, eastern North Pacific Ocean listed in historical records, 1880–1990.

Depth (fm)	No.	Specimen size (cm)	Location/distance from coast (n.mi.) for underlined specimens
0–5	3	9, 15, juv	Boat ramp, north jetty, Humboldt Bay, Calif.
5–25	2	17.5, 18.2	Off mouth of Columbia River
25–50	1	18.5	10 n.mi. W of San Pedro, Calif.
50–200	2	19, juv	10 n.mi. W of Redding Rock, Humboldt Co., Calif.
100–300	1	43	S. of Arena Canyon (no distance listed)
300–500	1	50	14 n.mi. WSW of Punta Gorda, Calif.
Total	10		

Table 5.—Date, size, and distance from coast of ragfish < 17 cm caught in surface waters by Oregon State University Department of Oceanography in horizontal and oblique midwater trawls over continental shelf, eastern North Pacific Ocean, off Oregon, 1962–76.

Date	No.	Range in SL (cm)	Trawling location	Trawl depth (fm)	Source of data[1,2]
8 Mar 62	1	6	40 n.mi. W of Cape Argo	0–100	Pearcy
25 Aug 66	1	7	59 n.mi. NW of Newport	0–500	Stein
15 Oct 66	1	juv	70 n.mi. W of Cape Fowlweather	0–600	Pearcy
14 Nov 70	3	1.5–3.0	65 n.mi. NW of Newport	0–45	Stein
6 Jul 70	1	5	19 n.mi. SW of sand spit, south entrance to Columbia River	0–1.5	Stein
6 Jul 70	1	11	19 n.mi. SW of sand spit, south entrance to Columbia River	8–15	Stein
20 Jul 76	1	5	80 n.mi W of Tillamook Bay	0–18	Pearcy
21 Aug 82	1	4	78 n.mi. W of Heceta Head	0–0	Pearcy
24 Aug 82	2	8–11	78 n.mi. W of Heceta Head	9–18	Pearcy
24 Aug 82	1	13	78 n.mi. W of Heceta Head	13–13	Pearcy
24 Aug 82	2	3–8	78 W of Heceta Head	145–154	Pearcy
No date	5	7–14	No data		Stein
No date	1	16.5	85 n.mi. W of Columbia River mouth		Pearcy
	21	1.5–16.5	Range from coast 19–85 n.mi.		

[1] Pearcy, W. Oregon State Univ., Corvallis. Personal commun., 1999.
[2] Stein, D. 1976. Response to survey by R. Behrstock, 1976–77.

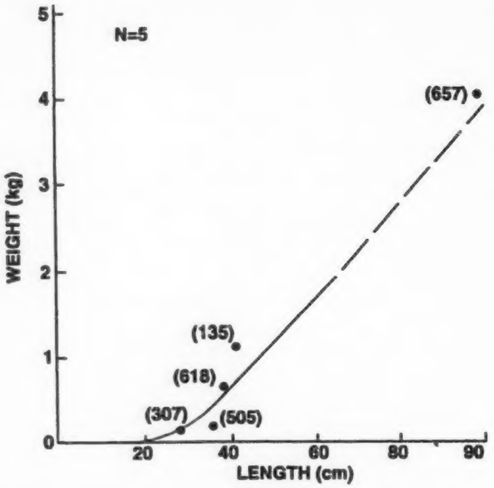

Figure 10.—Weight-length relationship of smallest ragfish recovered by NMFS research surveys along continental shelf of United States south of lat. 45.5°N, 1990–93. (Depth in meters of trawl shown in parentheses.)

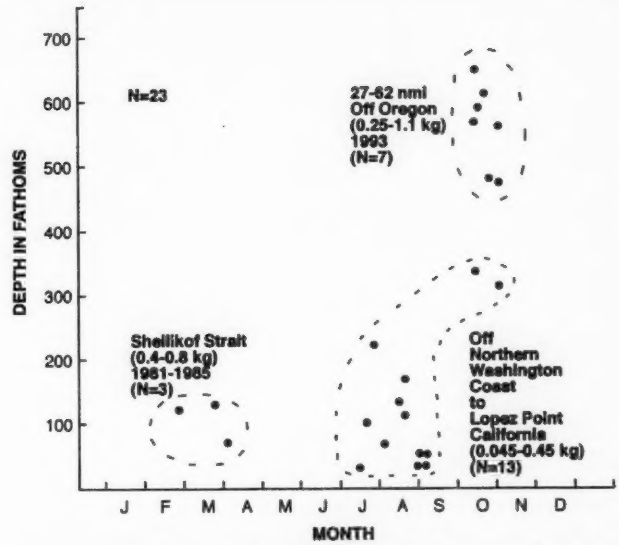

Figure 11.—Depth, location, and month of catch of small (<1.1 kg) ragfish recovered in NMFS research surveys (RACE), 1979–98.

found over all depths occupied by larger ragfish recorded from all areas and seasons (Table 7). These data all suggest that the transformation of small juveniles into larger immature fish occurs at about the same time that the pelvic fins are being reduced (Komori, 1993:30–36 cm). These smaller immature ragfish occurred in a range of depth and location comparable to those found for the larger adults. Over the extensive range of the ragfish, however, there continues a general paucity of data on ragfish life history between ELH stages and appearance of smaller juveniles noted by Matarese et al. (1984).

Sex Ratios

Early records could not establish sex ratios because immature juvenile ragfish dominated the samples available to taxonomists initially describing the species (Lockington, 1880). Subsequently, only a few mature females (Bean, 1887) appeared in the historical record, and this imbalance continued to modern times (Tables 1, 2). Historically, although, some males were reported, authors noted difficulty in assigning sex to specimens with developing gonads. For example, a 136 cm ragfish was caught 18 July 1935 by a fisherman in the proximity of Sooke Harbour, B.C. (BCPM 1935-1), for which the curator was uncertain if observations were of ova or some follicles with sperm (Peden[14]). Schultz et al. (1932), reporting on a 117 cm specimen, observed that the fish had "greatly enlarged and probably mature testes." Another example of tentative sex determination was made by the NMFS Auke Bay Laboratory on a 38 cm specimen (AB 61-38) taken in the Gulf of Alaska in September 1961 as follows: "The smaller one is in better condition and appears to be an immature female. The gonads are about 4 inches long and 1/4 to 1/2 inches broad. The material appeared granular and a few minute eggs could be separated." Ragfishes of intermediate sizes with questionable sex included two specimens taken 30 May 1962 in a midwater trawl (439–484 m) located 70–80 n.mi. west of Cape Flattery: a female 80 cm FL, 4.7 kg (BCFM: 972-62), and a male 99 cm FL, 6.9 kg (BCFM: 972-62).

Similar tentative decisions on sex were made on two intermediate-sized ragfishes taken in and around the head of Bodega Bay, Calif. A possible female measuring 77 cm was landed 10 January 1974 (CAS 31207), while the other was tentatively listed as a male 66.5 cm FL taken February 1963 (CAS 27468). One gonad in the HSU collection presenting an unusual appearance was listed as a presumed male of 100 cm FL (HSU 22) caught 23 April 1975 along the 400 fm (732 m) contour 25 miles west of Brookings, Oreg. The 24 cm long gonad filled the top of the abdominal cavity. The morphology that caused the curator's questioning of this decision on the sex of the fish was not recorded.

Most ragfish delivered to HSU could be sexed. Roughly three times more female ragfish exist in HSU records as compared to other institutions (Table 2). Historically, females were almost always longer than males (Fig. 12), and with a slight overlap in weight (Fig. 13). Initially such a condition was assumed to be sexual dimorphism, although a difference in habitat by males as well as protandric hermophrodism were also possible explanations for the disparate sex ratio. Only one gonad with an external appearance suggesting internal differentiation (HSU 25) was examined histologically, showing testicular tissue throughout. The only historical record reporting a mature male from the eastern Pacific Ocean was a specimen of

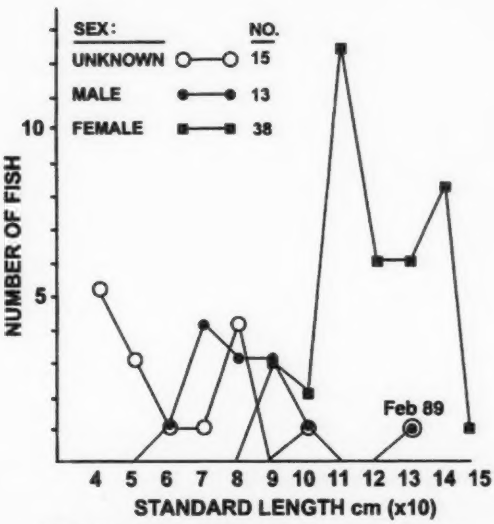

Figure 12.—Standard length (cm) by sex of ragfish >35 cm recorded from eastern Pacific Ocean, 1952–89 (male recovered February 1989 circled).

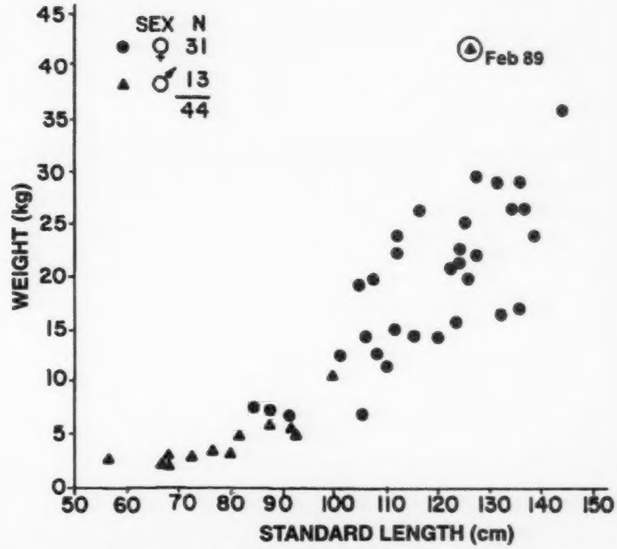

Figure 13.—Length-weight relationship by sex for ragfish >35 cm recorded from eastern North Pacific Ocean, 1952–89 (male recovered February 1989 circled).

167 cm caught November 1931 away from the open ocean in surface waters near Petersburg, Alaska (Schultz et al.,1932:65). The first confirmed male adult ragfish (95 cm) from the western Pacific Ocean was documented by Kubota and Uyeno (1971). The first unequivocal male ragfish seen by the author (HSU No. 35, FL 139 cm; SL 123 cm) (Fig. 14) was caught by a trawl in 480 fm (878 m) on 17 July 1989 fishing 25 n.mi. due west of Point St. George, Calif. This analysis of ragfish catches indicated that commercial fishing gear in northern California and southern Oregon were not fishing in areas primarily inhabited by large maturing males, and thus the unbalanced sex ratios as recorded were primarily a function of sampling bias.

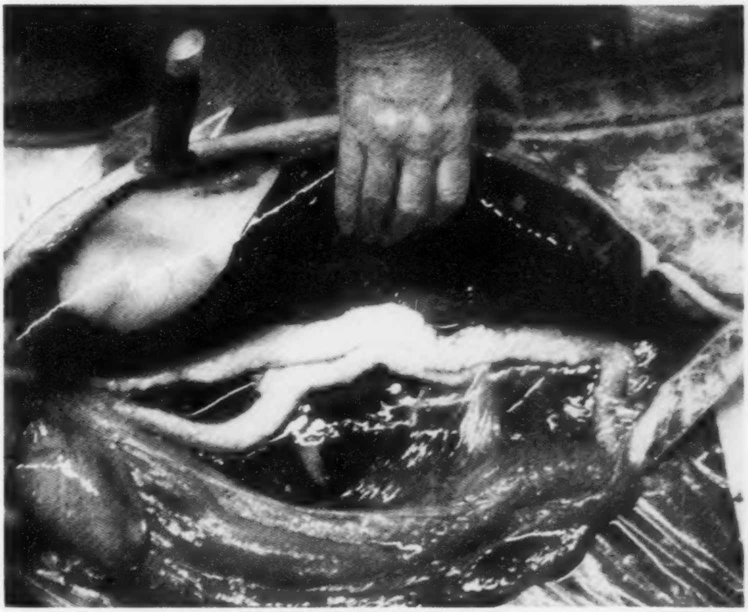

Figure 14.—Testes of male ragfish (HSU No. 35) shown in Figure 1. Testes 41 cm from anterior attachment to bend leading to vent, with testes length from bend to vent 7 cm. Photograph by G. Allen.

Reproduction

Most historical data available for documenting the reproductive biology of ragfish came from recoveries by commercial and research trawling off southern Oregon and northern California (Table 8; Fig. 15, Areas B and C). The coastal bathymetry of Areas B and C shows a narrow continental shelf that only tends to spread westward north of central Oregon (see Fig. 1 in Pearcy, 1964). South of Cape Mendocino the continental shelf is relatively narrow and incised with submarine canyons. Over time the commercial bottom trawl fishery in Areas B and C moved to deeper waters beginning around 1970,

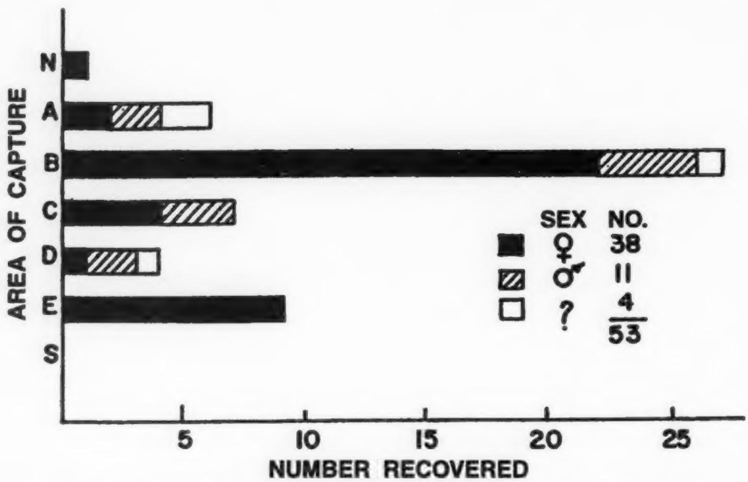

Figure 15.—Number of ragfish by sex recovered by areas from eastern North Pacific Ocean, 1952–89. Recovery areas are described in Table 8.

Table 8.—Recovery areas used for analysis of historical data on reproduction and other aspects of ragfish biology in the eastern North Pacific Ocean, 1899–1989.

Area number	Description	Principle ports of ragfish recovery
N	Washington, British Columbia, and Gulf of Alaska	
A	Oregon coast north of Point St. George	Brookings, Oreg.
B	Point St. George south to Cape Mendocino, Calif.	Crescent City, Calif. Eureka, Calif.
C	Cape Mendocino to Point Arena, Calif.	Ft. Bragg, Calif.
D	Point Arena to Farallon Islands, Calif.	Bodega Bay, Calif.
E	Farallon Islands to Point Sur, Calif.	
S	Central and southern California coast	

with a yearly fishing pattern illustrated for both periods (Fig. 16). Most large ragfish (>35 cm FL) forwarded to HSU or CDFG were caught in Area B, with most of these coming from the northern portion of the area (Trinidad Head to Point St. George). Depths of trawls taking ragfish ranged from less than 44 fm (81 m) to over 620 fm (1,135 m) (Fig. 17). Female ragfish were caught more frequently in shallower depths than males in Area B (Table 9).

Fitch and Lavenberg (1968), on the basis of a single running-ripe female, postulated that a summer appearance of such large maturing females as shown for all west coast areas (Fig. 18) and Area B (Fig. 19) reflected a spawning movement onto the shelf. Such concentrations, however, could also have resulted from feeding behaviors. This hypothesis was examined by examining ragfish anatomy and studying food habits of ragfish along the continental shelf.

Adult ragfish have minute teeth in their jaws and a thin-walled digestive tract with no discernible differentiation between stomach and intestinal tract. This morphology is suited for consuming soft and readily digestible material. There are scant data in museums, literature records, or from recent records by biologists with personal knowledge of ragfish concerning stomach contents. Fitch and Lavenberg (1968) noted "small red jellyfish" in the stomach of a 27 cm juvenile recovered July 1962, 25 n.mi. east of San Clemente Island, as well as small fishes, squid, and octopuses in other specimens familiar to them. Research gear used to investigate scattering layers formed by walleye pollock, lantern fish (Myctophidae), and euphausids in lower Chatham Strait, Alaska, took a 130 cm

Table 9.—Difference in depth of capture[1] between number of male and female ragfish taken in commercial otter trawls operating between Trinidad Head and Cape Mendocino, northern California, 1958–89.

	Numer by sex		
Trawl depth (fm)	Male	Female	Total
<350	2	15	17
>350	8	3	11
Total	10	18	28

[1] Chi-squared test of hypothesis that there is no difference in depth distribution between sexes using Yates continuity correction, equation 6.8, p. 64, in Zar, 1968: $\chi^2 = 8.32$; df = 1; $P = <0.005$.

adult ragfish which had consumed only lantern fish (Bracken[10]). Their midwater trawl was towed at 75 fathoms (137 m) over an ocean bottom of 300 fathom (549 m) depth.

Recorded observations by CDFG and HSU on the stomach contents of 34 ragfish caught in Area B (Table 8) showed about 65 percent of the stomachs empty or only containing traces of material. Specific comments on material seen in six stomachs were: "yellowish material at the lower end of the intestine," or "runny orange liquid." Only a single stomach (106 cm female, HSU No. 4) had identifiable material, a single, 15 cm FL shortspine thornyhead, *Sebastolobus alascanus*. The rockfish's red skin was clearly visible through the stomach wall and presumably the ragfish had consumed the rockfish while in or just prior to retrieval of the trawl net. The trawl occurred at 100 fm (183 m) southwest of Humboldt Bay. A second example of freshly consumed prey was that of an eelpout (Zoarcidae) found 8 August 1977 in the gullet of a 137 cm long ragfish caught 7 n.mi. west of the entrance to Humboldt Bay in 80 fm. Thus from HSU and CDFG data it appears that ragfish being taken off the continental shelf between Cape Mendocino and Trinidad Head were not in the area for any vigorous or sustained feeding.

The spawning time of ragfish was investigated by examining seasonal changes in the morphology of testes and ovaries from specimens primarily recovered from Area B. These changes included qualitative observations on the condition of ragfish testes, the relative change in size of ovaries of females throughout the year, and the change in mean diameter of large-category eggs

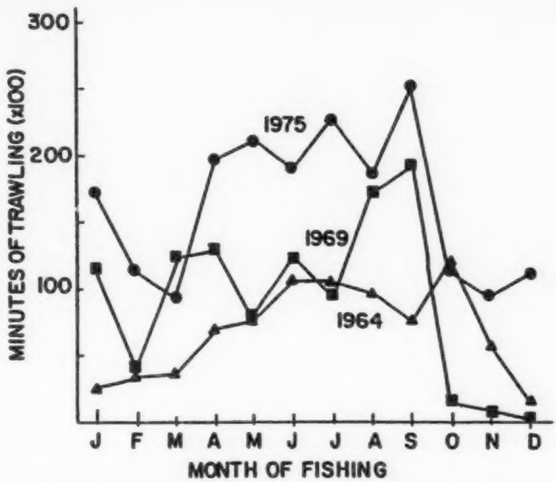

Figure 16.—Monthly fishing effort in bottom trawl fishery from False Cape, Calif., to Cape Blanco, Oreg., 1964, 1969, 1975.

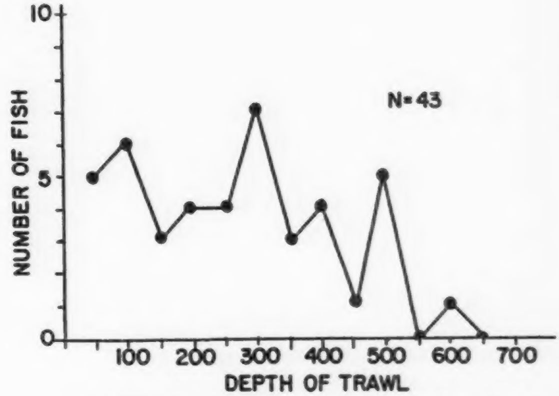

Figure 17.—Depth by 50 fm (100 m) intervals of trawls capturing ragfish >35 cm SL off the Pacific coast of North America, 1952–89.

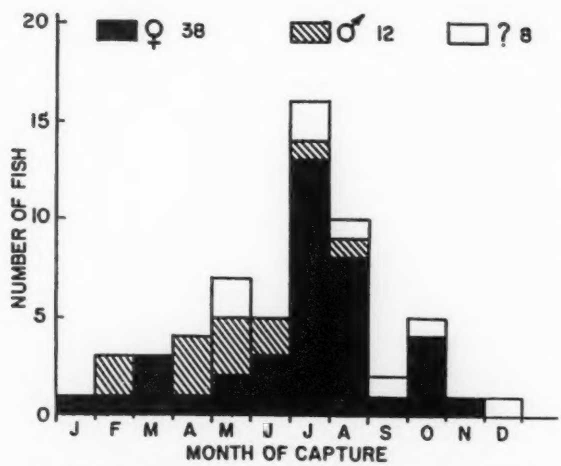

Figure 18.—Month of capture of ragfish >35 cm SL by sex in trawls off the Pacific coast of North America, 1952–89.

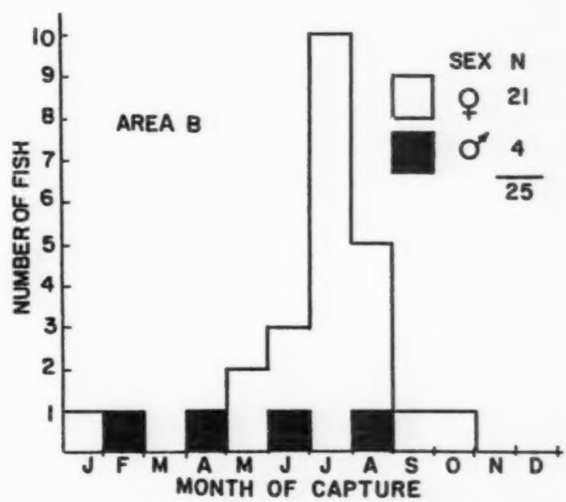

Figure 19.—Month of capture of ragfish >35 cm SL by sex in trawls in Area B (Point St. George to Cape Mendocino, Calif.) 1952–89.

in ovaries over time. Only four male ragfish taken off northern California and southern Oregon were available for comparative gonad size as indicators of spawning period. A small male, 77 cm SL (CAS 31207) taken January 1974 north of Bodega Canyon showed a "very thin testes." Relatively large and mature testes were noted in a specimen taken in late April 1975 (total testis length of 24 cm as compared to SL of 92 cm). Testes of a large male ragfish landed in Eureka, Calif., on 1 March 1989 were relatively small (25 cm maximum length in a 126 SL fish). The gonad showed typical testicular external morphology of lobate folds (2–3 cm in diameter) of cream-white tissue. The right testis was nestled into the left testis, with the remaining anterior and posterior portions of both testes being very small in diameter. For a 139 cm TL ragfish landed in July 1989, both testes were 41 cm long (Fig. 14). Thus both full and depleted testes were noted in all seasons of the year. HSU ragfish and those measured at other institutions had right and left testes of equal length,

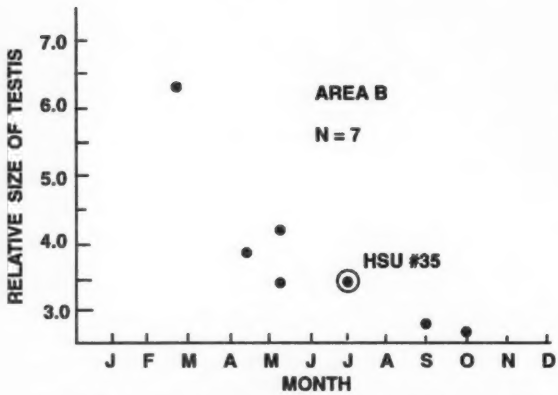

Figure 20.—Relative size of lobulose section of testes of male ragfish captured by month in Area B (Cape Mendocino to Pt. St. George, Calif.) 1958–89. (Specimen HSU 35 shown in Figures 1 and 14).

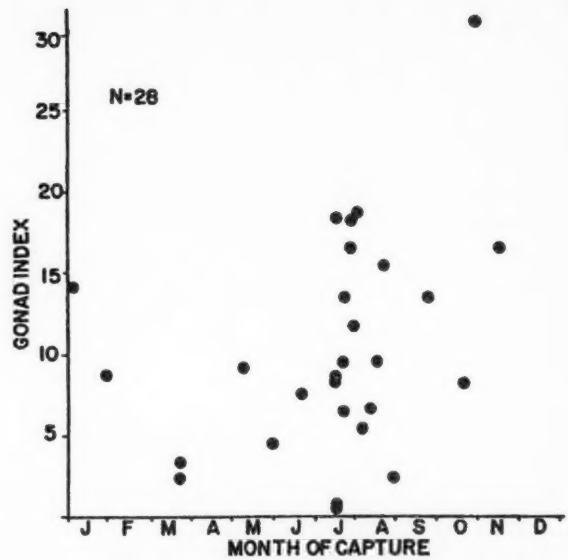

Figure 21.—Relative size of ovary (gonad index) compared to month of capture of female ragfish recorded from eastern North Pacific Ocean, 1952–89. Gonad index = gonad wt (kg)/SL(cm)^3 × (10^7).

or with either testis being larger. Lobulate tissue had developed at various positions along the testes, and varied in position between left and right testis. As another possible indicator of time of spawning, I calculated an index of relative length of the lobulate portion of testes (standard length divided by the length of the lobulate section). This index, when plotted against month of capture from Area B, suggested testis development most advanced in a late winter–early spring period (Fig. 20). Further comparative observations on testes from fish recovered in other seasons are needed to assess inferences on time of spawning based on testes morphology.

Females with ovaries having free-running eggs were captured at all seasons of the year (July–4; August–2; October, November, and January–1 each). Records on two females recovered in May had no comments as to eggs flowing from the vent but did have comments that eggs appeared relatively small. An index of relative size of ovaries plotted against time (Fig. 21) was highly variable, with a slight tendency for larger indices in spring. The strongest indicator of time of spawning, however, was found by a steadily increasing diameter for large-category eggs from late spring through summer and fall to early winter (Fig. 22).

In summary, this analysis of ragfish spawning time in northern California and southern Oregon based on testis and ovary maturity indicated a period from late winter to early spring. This is a slightly more restricted spawning period than that of late winter to early summer as previously proposed (Allen, 1968; Fitch and Lavenberg, 1968; Hart 1973).

The imprecise place of capture of a ragfish in the course of a bottom trawl makes it impossible to locate spawning areas even when data are available on gonads and coordinates at beginning and end of trawl hauls. Another approach to delineate a spawning location was made by examining the place of capture of these females showing the greatest diversity in their fecundity and also by examining the size and development of ragfish eggs. Four large females showed obvious disparity from a linear fecundity-weight relationship (Fig. 24). Catch details of these fish grouped into two sets (fish A and D, and fish B and C) are shown in Table 10. Females taken in the fall and winter (A, D) had the larger-sized eggs that were freely flowing from the vent, and they were both captured relatively near the north bank of the Eel River Canyon. Females captured in spring and summer (B, C) had the smaller-sized eggs, did not have eggs recorded as freely flowing from the vent, and were captured further away from the Eel River Canyon. As noted, the only ovary in the sample whose morphology indicated recent spawning was a specimen (HSU 8) taken 20 March 1969 off Bodega Bay in a commercial trawl of 270 fm (494 m) maximum depth. Unfortunately, there were no coordinates or directions to precisely locate the place of trawling, although it appeared to be near the head of Bodega Canyon.

A standard approach to delineating a possible time and place of spawning of a marine species utilized the size and development of eggs and larvae sampled over a probable spawning habitat. This approach was possible for ragfish using ELH data in both published and unpublished reports. The distribution of large eggs in icthyoplankton surveys could sug-

Table 10.—Capture information and biological indices for four specimens of ragfish with maximum variation from fecundity-weight regression (fish numbers A–D, Fig. 21).

Fish no.	Date captured	Approximate location	Depth (fm)	Gonado-tropic index	Mean egg diameter (mm)	Free-flowing eggs
A	29 Oct 67	8 n.mi. west of Eureka, Calif.	330–290	14.1	2.6	Yes
B	13 Jul 72	19 n.mi. west McKinleyville, Calif.	44	18.3	1.6	Not recorded
C	21 May 74	Off Redding Rock, Calif.	180–250	9.2	1.6	No
D	2 Jan 62	North edge of Eel River Canyon, Calif.	180–190	30.9	2.7	Yes

Table 11.—Fecundity estimation of total number of "large-diameter" eggs for 14 female ragfish recovered from commercial trawl fisheries of the eastern North Pacific Ocean over the northern California and southern Oregon continental shelf (area B, Table 8), 1958–81.

HSU fish no.	Weight (kg)	Length (cm) TL (SL)	Total ovarian weight (g) (TOW)	Ovarian case weight (g) (OCW)[1]	Weight of eggs and ovarian tissue (g) (TOW-OCW) (A)	Average no. eggs per g of tissue (B)	Fecundity (thousands of eggs) (A × B)
1	26.2	150 (135)	1,647	(92.8)	(1,554)	260	404
3	30.0	150 (127)	3,402	(139.2)	(3,263)	79	257
4	19.5	119 (106)	989	(74.0)	(915)	265	242
5	23.1	129 (124)	3,339	176	3,163	123	390
6	21.6	143 (124)	5,942	209.0	5,733	92	527
7	26.8	122 (106)	2,236	(107.7)	(2,128)	184	391
9	7.9	89 (85)	516	(61.2)	(455.1)	250	114
13	12.2	125 (101)	680	60.7	619.7	250	155
14	15.4	129 (112)	1,918	(99.0)	(1,819.0)	148	270
15	24.4	129 (115)	2,590	84	2,506.1	220	552
20	25.6	142 (125)	1,805	125.9	1,679.4	310	521
21	14.4	135 (121)	803	65.0	739.9	274	202
23	21.8	133 (122)	1,523	107.3	1,415.7	231	327
24	14.5	128 (106)	930	60.7	869.2	288	250

[1] OCW shown in parentheses estimated from regression of ovarian case weight against ovary weight as follows: OCW = 0.027 (TOW) + 47.3, $n = 7$, $R = 0.92$.

gest a time and place of ragfish spawning since there are only a few marine species along the continental shelf with egg sizes as large as those of the ragfish and none with a similar distinct external pattern (Fig. 7).

Eggs with diameters similar to the "large category" eggs of ragfish were reported taken in February plankton samples off Eureka (Luczkovich[17]), but other ELH studies conducted by HSU faculty restricted to Humboldt Bay or nearshore waters found no ragfish eggs or larvae (Barnhart[18], Crandell[19]). Lack of eggs in shallow nearshore areas off Eureka may be related to a scarcity of adult ragfish in Area B nearshore as shown by the absence of ragfish reported from catches in commercial shrimp trawling in shallow waters (120 fm (220 m) or less) and/or in the salmon troll fisheries of the same areas off the northern California coast as compared to the consistent recoveries of ragfish from bottom trawlers operating in deeper waters to the west. In summary, these limited observations suggest a mesopelagic or mesobenthal spawning location, possibly associated with canyon heads along continental shelves.

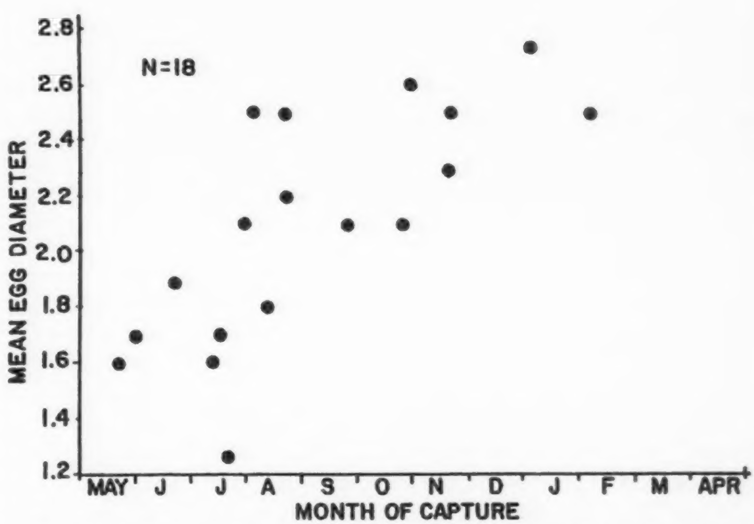

Figure 22.—Change in mean egg diameter (mm) in ragfish ovaries from specimens captured off northern California and southern Oregon, 1958–89. Maturation (mean egg diameter mm) = 1.06 + 0.0035 day of capture (Julian year); (Bremm, 1980, unpubl. rep. on file with G. Allen, HSU).

Historically, fecundity (number of "large-category" eggs) calculated from ovaries of 5 large female ragfish captured in northern California–southern Oregon ranged from 230,000 to 430,000 eggs (Allen, 1968). Subsequently, an additional 9 females were available to expand this fecundity range to 144,000–552,000 eggs (Table 11). In historical records ragfish over 6 feet (183 cm, Fig. 2C) long were much longer than the females shown

[17]Luczkovich, J. 1989. Adjunct Prof., Humboldt State Univ. Fish. Dep., Arcata, Calif. Personal commun.

[18]Barnhart, R. 1999. Calif. Coop. Fish. Res. Unit, Humboldt State Univ. Personal commun.

[19]Crandell, G. 1999. Dep. Oceanogr., Humboldt State Univ. Personal commun.

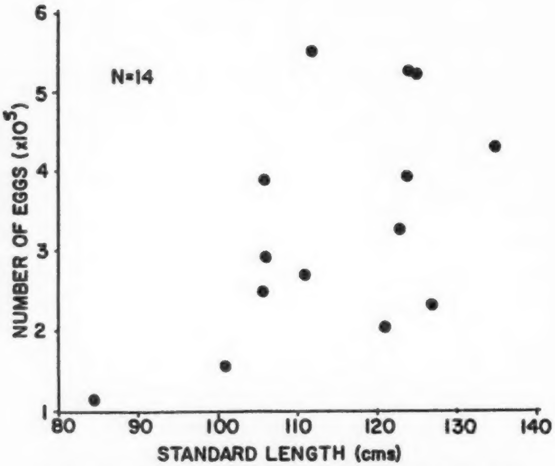

Figure 23.—Fecundity of ragfish compared with standard length (cm) of females recovered off northern California and southern Oregon, 1952–89. (ln-ln regression of fecundity (fec) against length (mm); ln (fec) = –4.0422 + 2.3210 × length; $R^2 = 0.42$; with exponentiation giving: fec = $e^{-4.0422}$ × len2.321 = 0.01756 × len$^{2.321}$).

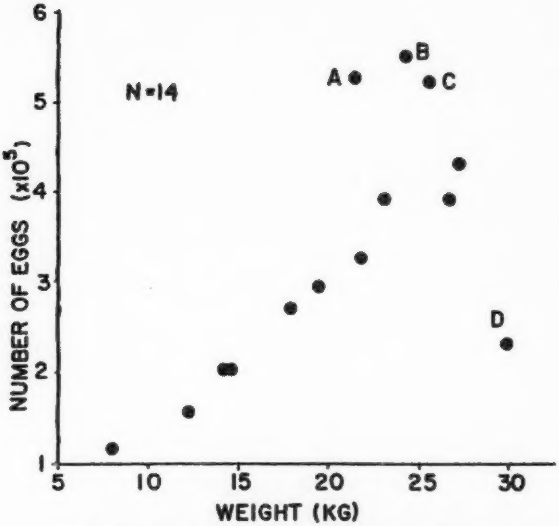

Figure 24.—Fecundity of ragfish compared with weight (kg) of females recovered off northern California and southern Oregon, 1952–89. The text explains points A–D. Regression of fecundity against weight in kg: fec = 23776 + 14996 × Wt; $R^2 = 0.48$.

in Table 11 used in estimating ragfish fecundity. Lengths of the larger ragfish in the historical record were imprecise since authors reporting the data rarely examined the specimens personally. Sex of larger specimens also were rarely reported. One large specimen with accurate data was that of a 183 cm female reported by Pritchard (1929). I feel that the largest ragfish on record reported by Cowan (1938:208 cm) could be assumed to be a female. The weight of these 183 and 208 cm specimens were estimated by use of a length-weight regression calculated for the 14 females as listed in Table 11 ((ln weight in kg) = –12,5500 + 2.1613ln (length in mm); $R^2 = 0.57$; or weight = $3.544902 \times 10^{-6} \times \text{length}^{2.1613}$)). Predicted weights were 38.94 and 52.59 kg, respectively. Using regressions of fecundity against length (Fig. 23), the predicted fecundities were 640,000 and 883,000 eggs, while using fecundity against weight (Fig. 24) predicted fecundities were slightly lower: 608,000 and 813,000 eggs. Ragfish fecundity of over 1 million eggs should be expected, since specimens larger than the 208 cm ragfish probably exist (Cowan, 1938).

Ragfish appear to discharge eggs in a single short spawning burst. This is suggested by the lack of any difference in the mean size of large-category eggs in the ovaries (Allen, 1968 and Table 11 in this study). This idea was strongly supported by the recovery of one female as noted earlier taken 20 March 1969 off Bodega Bay at 270 fm (494 m) near the head of Bodega Canyon. The ovarian surface was highly vascularized and bleeding, virtually devoid of eggs, and had a few fragile and easily ruptured eggs running from the vents.

Temperature and Ragfish Life History

Ragfish are regarded as coldwater fish of the subarctic zoogeographic region of the North Pacific Ocean which lies north of the 8–10°C surface isotherm where it is associated with Bramidae (pomfret, *Brama japonica*), Anoplopomatidae (skilfish, *Erelipis zonifer*), and Salmonidae (Pacific salmon, *Oncorhynchus* spp., (Moyle and Cech, 1996: Fig. 26.2). It is likely the ragfish would respond to changes in location of surface isotherms as reported for other members of this assemblage (see papers in Wooster and Fluharty, 1985). Temperature records accompanying ragfish captures reported in NMFS databases (RACE and REFM) are in the normal "cold-water" range (7.5°–10°C); however, temperatures as low as 2.5°C have been reported with ragfish taken at deeper depths (Fig. 25, 26).

Both minimum and maximum water temperatures recorded for ragfish catches occurred along the U.S. continental shelf. There were, however, a fairly large percentage of both small subadults, and even adults, recovered in warmer shallow waters, including surf zones. Presumably the eggs and larvae up to 3 cm TL that inhabit offshore surface waters are also in warmer waters.

Correlations of ragfish catches in 1962 with dramatic decreases in water temperatures off Japan in 1963 have been made by Abe (1963) and Nakai et al. (1964). The study involved over 35 juvenile and subadults caught from 21 March to 18 May 1963, only 800 m (0.5 mi) off the Pacific coast of Japan (Abe 1954, 1963). The catches were made along the 100 fm (183 m) contour which lies about 5 n.mi. offshore, beyond

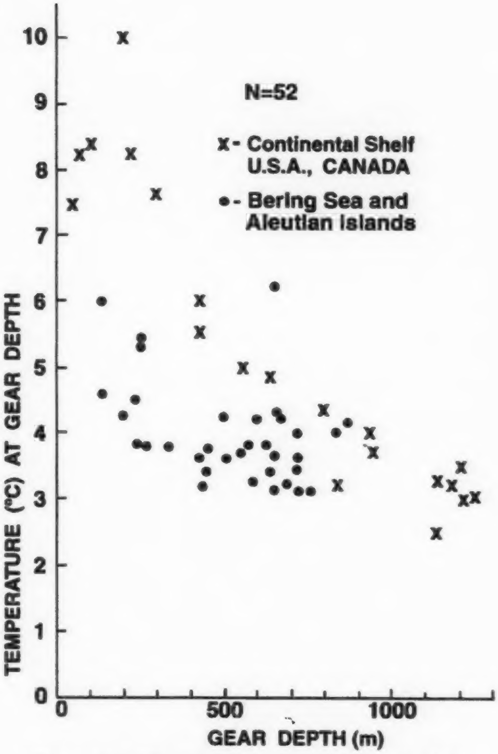

Figure 25.—Water temperature at trawl depth taking ragfish compared to surface temperatures by region, NMFS RACE surveys (research trawling), 1976–99.

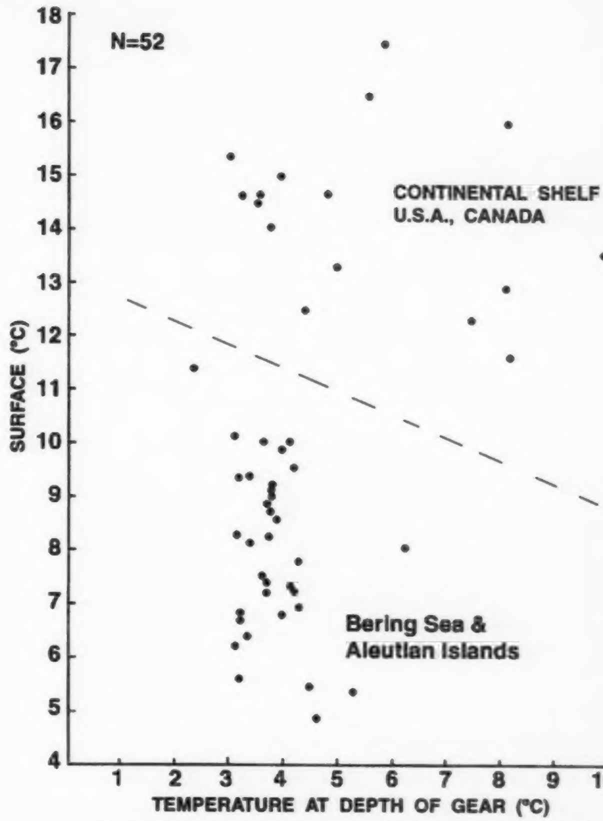

Figure 26.—Comparison of water temperature at depth of trawling taking ragfish by region, NMFS research trawling, 1976–98.

which the sea floor drops off sharply to a 500–700 fm (914–1,280 m) depth. The Japanese oceanographic surveys in the area were stimulated by the destruction of local fisheries from a replacement of the normal warm Kurisho current flowing north along the coast by large volumes of colder water as measured by oceanographic studies in 1963 in the Cape Manazuru area during late winter (25 January–20 March) and late spring (25 April–3 June) periods (Nakai et al., 1964). For the early spring studies, Nakai et al. (1964:62) concluded that "The temperature-chlorinity characteristic at the cold water area that occurred in the Sea of Kashima-Nada showed a very close resemblance to that of the sea in the northern Pacific which was reported as found in summer season. This fact suggests that this cold water was not an upwelling of bottom water but due to southern movement of Oyashio."

Abe (1963), in reporting on the ragfish occurrences off Cape Manazurau, noted that one fish was taken 21 April 1963 when water conditions from 20–22 April at 2, 30, and 50 m depths varied from 13.8° to 14.6°C. In 1963, a few locations off the Pacific coast of Japan showed a 14°C drop in water temperature from 1962. Abe (1963) did not state what the normal warmwater temperatures for the area had been, but presumably the area reflected the usual 18°–19°C surface temperature along the Kurishio axis reported by Nakai et al. (1964). Abe (1963) also noted that other ragfish were recovered off the coast of Japan in 1953 during another cold-water year. The intrusion of pulses of cold waters, either by upwelling or southward movement of North Pacific waters, entrains ragfishes, making them susceptible to capture in the near-shore Japanese fisheries. Wing[11] also suggested that large ragfish caught in southeastern Alaska deepwater channels and inlets probably were entrained in surges or pulses of open ocean waters.

I did not attempt to study the correlations of inshore ragfish recoveries with possible occurrence of cold-water intrusions reported in recent literature (Wooster and Fluharty, 1985; McMurray and Bailey, 1998). El Niño effects, however, focus mostly on the changes in water temperature in ocean surface layers. The complex deeper ocean currents along the continental shelf of the eastern North Pacific Ocean (Greenland,

Table 12.—Published illustrations showing coloration pattern and snout profile of juvenile ragfish.

Example	Author and location	Type of illustration	Specimen size (cm)	Place of recording or capture
A	Günther (1887), Pl. XLIV	Line drawing	18–28 (n=2)	San Francisco, Calif.
B	Goode and Bean (1895), Fig. 224, Pl. LXII	Line drawing		San Francisco, Calif.
C	Fitch (1953), Fig. 4, p. 545	Photograph	20	San Pedro, Calif.
D	Abe (1954), Fig. 3, p. 94	Line drawing	26	Oya-mura, Northern Japan
E	Abe (1954), p. 94	(Written description)		Manazura, central Japan
F	Clemens and Wilby (1961), Fig. 138a, p. 235	Line drawing		Strait of Juan de Fuca,Canada
G	Kamohara (1962), Fig. 3, p. 6	Photograph	27	Urado Bay, Kochi City, Southern Japan
H	Hart (1973), p. 386	Line drawing		Canada
I	Allen, G.H., and G. Theisfield[1]	Preserved, HSU museum	19–36 (n=5)	Northern California

[1] Observation on specimens.

1998: Table 4.4) have not yet been sufficiently documented to be useful in understanding historical catches of ragfish with changing water temperatures. The known importance of temperature in the ecology of marine fishes (Karinen et al., 1985), the recent elaboration of coastal upwelling and eddy formation in the California Current system (Greenland, 1998: Fig. 4.31), and similar oceanographic phenomena off southern Alaska coasts, could be part of explaining how ragfish periodically appear in shallow continental waters and in deeper inlets and fjords. As noted, the dead or moribund specimens which have been recovered by hand collections in the relatively warmer waters adjacent to beaches could come from a combination of a sensitivity to high temperatures, physiological stress from lack of a pneumatic duct, and an increased buoyancy in females carrying ovaries with eggs in advanced ripening stages. The southern boundaries of North Pacific regions of warm-cold water interfaces vary both with seasons and major changes in weather (McMurray and Bailey, 1998) (e.g. El Nino and La Nina events).

Cold-water intrusions both over continental shelf zones and upward into surface epipelagic waters could readily entrain ragfish into nominally temperate-water regions. Schoener and Fluharty (1985: Fig. 1, p. 212), reporting on a ragfish taken in 1983 in Hood Canal, Wash., listed the specimen as showing a "habitat anomaly." Historical records of ragfish taken from inland marine waters of Washington and British Columbia support ragfish as normal residents and thus does not indicate the presence of the specimen was related to 1982–83 El Niño effects. There was some indication of a reduced recovery of ragfish from northern California waters following the 1976–77 and 1982–83 El Niño events (Fig. 4). Substantiating any warmwater avoidance behavior by ragfish would be difficult because of the complexity of nearshore currents off northern California (Allen, 1964) and the west coast continental shelf areas in general (Pearcy, 1964).

Population Possibilities

Ragfish populations distributed in the North Pacific Ocean along continental shelf zones from southern California to southern Japan might be expected to have differences in morphological and other biological characteristics. I did not attempt to compare meristics and morphometric data on adults listed in the literature, but I did attempt a cursory study of coloration and head morphology of eight juveniles illustrated (Grinols, 1965) or described in the literature, and of five juveniles (19–36 cm) preserved in the HSU fish museum (Table 12). Most juveniles illustrated or described in the literature showed a lateral head profile described as "trout-like" (Fitch and Lavenberg, 1971), except for Example C (Table 12) taken off San Pedro, Calif. Fifty years earlier in 1921, Higgins described the head of a 22 cm juvenile as follows: "The mouth was large, with thick lips, the nose broad and rounded, resembling with its large nostrils the muzzle of a calf." All five HSU juveniles shows this same broad, blunt-nosed profile a shape reflected in the line drawing of an adult ragfish illustrated in Hart (1973: 386). Hart (1973) also depicted a juvenile with the "trout-like" appearance. Thus, the uncertainty surrounding changes in head shape comes from both "trout-like" and "calf-like" head morphologies having been described for both juveniles and adults. Head profiles may thus vary with the eye of the illustrator and the audience. Hart (1973) summarizing the situation succinctly as "All that is known about the remarkable metamorphosis of this species from juvenile to adult is the change itself."

Skin coloration and markings of fishes is highly variable as influenced by ontogeny and habitat. Not only does variability exist in the natural world, but changes in color and fading accompany immersion of specimens in preservatives. This problem was addressed in the initial description using two juveniles available to Lockington (1880) as follows:

> "Color–Purple spots and blotches of irregular shape upon a yellowish-brown ground; the spots largest upon the dorsal region, and becoming smaller and more numerous near the lateral line. The regions above and behind the pectorals beset with numerous purple spots, smaller than those above the lateral line. Beneath the lateral line, on the posterior part of the body, there are no spots, except along the line of the anal; but probably this is the result of the exposure to alcohol, which has caused the disappearance of most of the spots from the smaller specimen, the color of which, when fresher, was like that of the larger. Throat and greater portion of gill-membranes without blotches, but shown with dark points, which occur also over the whole of the body and interior of the mouth. Fleshy bases of caudal pectorals with several purple blotches. Fins darker than the body, and showing traces of blotches of a deeper tinge, especially upon the caudal."

Lockington and other early ichthyologists did not have the possibility of colored photographs, and even colored illustrations were a luxury.

Günther (1887) described color briefly in his description: "The fish is of a very light coloration, transparent below the dorsal and above the anal; its upper half is marked with large blackish spots, irregular in shape, smaller on the head and neck than on the rest of the body; they form a series along the base of the vertical fins, which are similarly spotted.." Goode and Bean (1895) listed a description similar to previous authors, and did not include any comments on the color of their illustrated specimen.

Accounts of the color of Japanese juvenile ragfish are rare, with Kamohara's 1962 description including notes on color as follows: "Color pellucid yellowish, with purplish spots and blotches of irregular form; the spots largest upon dorsal region, and becoming smaller and more numerous near lateral line; pale below. Fins dusky, obscurely blotched, fleshy bases of caudal and pectorals spotted." Reexamination of juveniles in the HSU collection found two distinct skin colorations: very light to light skin color with prominent blotches and spots (19, 29 cm FL) and various shades of brown resembling adult skin color, with spots lacking (35, 36 cm FL and one specimen of 28 cm TL with missing tail). These data hint that skin coloration change is taking place simultaneously with reduction of the pelvic fins in a 30–36 cm range as documented by Komori (1993).

As would be expected, markings on juvenile ragfish undergo dramatic changes through larvae, juvenile, and adult stages. Watson (1996) reports that larvae less than about 2 cm have pigmentation as follows: "The light to moderate larval pigmentation occurs primarily on the head, gut, dorsum and finfolds and changes relatively during development." Very few ragfish have been accessed or described during growth to around 15 cm. Black spots and blotches forming patterns on the skin of juvenile ragfish as illustrated or described in the literature (Table 12) with minor variations in these patterns are relatively similar for specimens from California (Table 12 A, B, C) and Japan (Table 12 I). A photograph of a juvenile from Japan showed a highly spotted pattern (Table 12 D), but may be the result of photographing a fresh juvenile (26 cm TL).

These markings differed somewhat from a 15 cm TL fish described in the same paper (Abe, 1954) as follows: "The black markings of the body are relatively much larger and less numerous, and the posterior half of the body is much thinner than in the specimen from Oya-mura; . . . ." This comparison of Japanese specimens of different sizes was duplicated in part by a change in spotting with size found in the five northern California specimens. The smallest (19 cm SL) was uniformly covered with many blotches and large spots, while spotting was evident but hard to discern on a 29 cm FL specimen. No spotting was discernable on three larger juveniles (18+, 35, 36 SL). The juvenile illustrated by line drawing in Clemens and Wilby (1961) showed a uniform pattern of similar sized spots over the entire flanks, which I suggest is an artifact produced by the illustrator.

As with coloration, highly variable patterns of spots characterize juveniles from all parts of the North Pacific. Color photographs and descriptions of fresh-caught specimens are needed to ascertain if spotting might characterize local populations. Protein and DNA analysis might help to explain variability induced by environmental condition, and could lead to identifying possible distinctive populations in the species.

Other Life History Facets

The lateral line of adult ragfish is readily recognized as a prominent external structure (Fig. 3B). The young boys providing Bracken[10] with a large adult ragfish they found on a beach near Petersburg reported feeling tingles in their hands from handling the specimens, presumably from the spines associated with the lateral line. Descriptions of ragfish external morphology note that the lateral line is punctuated with modified scales or scutes in juveniles which become much reduced in adults (Cohn, 1906). He described in some detail the complicated lateral line in ragfish and associated structures (scales with and without spines), and compared them with other marine species. The smallish solid spines (less than 1 mm) growing out of several types of lateral-line scales have a complex association with pigmented and nonpigmented areas of skin. There were no described structures, however, that appeared to have toxic glands or secretory cells. If indeed reports on painful sensations that arise from handling living or moribund ragfish are true, pigmentations associated with skin may be a possible source of an irritating substance. Also there may be a lateral-line function in reproduction, such as the scales and spines acting as a tactile organ stimulating the release of eggs.

Possessing no scales and with only a cartilaginous skeleton, the ragfish is difficult to age using traditional methods. Otoliths were examined as a method of aging ragfish (Fitch and Lavenberg, 1971). Robert Behrstock, HSU fish collection curator, was unsuccessful at locating otoliths in large ragfish as indicated by entries into museum records. In January 1999, I examined a pair of otoliths removed by J. Fitch and preserved by L. Quirrolo, CDFG, Eureka, Calif., from a 115 cm ragfish. They were round, flattened, and only 1.5 mm in diameter. Fitch[20] reported unsuccessful attempts to interpret age from sections of otoliths, and was contemplating crystallographic and mineralogic studies. The only result of his preliminary aging of ragfish was that "An examination of otoliths of several ragfish 10 inches to 15 inches long indicates that the spotted phase lasts less than a year" (Fitch and Lavenberg, 1971: 80). Presence of modes in a length-frequency graph as indicators of fish age was equivocal for small (<35 cm) immature fish recorded in the historical data from museum collections (Fig. 9). The two modes neither negated nor affirmed Fitch's[20] statements.

Modes in length-frequency plots for ragfish >35 cm SL (Fig. 16) recovered off northern California and southern Oregon, were assumed to reflect the relative abundance of large maturing females and smaller males taken by the trawl fishery rather than any obvious age categories. A weight-frequency distribu-

[20]Fitch, J. E. 1976. Operations Res. Branch, Calif. Dep. Fish Game. Personal commun.: Letter to R. Behrstock.

tion of ragfish caught by NMFS research trawling operating on the continental shelf of the eastern North Pacific Ocean south of the Strait of Juan de Fuca suggested a first-year growth of up to 1 kg or less (Table 7). My initial analysis of the NMFS (RACE, REFM programs) ragfish size data, presented in this paper, supports the hypothesis of juvenile ragfish being more abundant at the southern end of their range in the eastern Pacific as well as in the western Pacific Ocean off Japan (Kubota and Uyeno, 1971).

Unravelling ragfish ecology undoubtedly will include information on population density. Estimation of population densities was not possible using historical analysis; however, there are recent reports on ragfish densities. Larkins (1964) calculated a density index of less than one ragfish per 100 shackles of gillnet fished in six areas of the North Pacific covered by Canadian research surveys. Currently, NMFS databases (RACE) can provide data for density estimates. The NMFS Observer Program (REFM) between 1990 and 1999 recorded 523 ragfish (Table 3, Fishery Observers, col. C) from all commercial fisheries of the west coast of the United States and the Bering Sea studied. This gives an average of only 52 ragfish per year recovered over the wide area covered.

A detailed study of the location and intensity of commercial bottom fisheries trawling efforts could be compared to ragfish recovery locations to study further the historical and the current hypothesis that ragfish populations have very low ragfish densities. A crude index of ragfish density, however, can be made from the number of specimens reported per year by the NMFS commercial fisheries observer and survey programs from 1976 to 1999. For all commercial fishing areas covered by the programs, the mean rate of recovery was 30/yr; for the U.S. west coast 5/yr; and for the Oregon and California coasts l/yr. This Oregon and California recovery rate is the same order of magnitude as found in the HSU/CDFG data bank of 2/yr for northern California from Cape Mendocino to Trinidad Head. For any area of interest a calculation of volume of water strained by all nets in individual fisheries, compared to the total water volume in a defined fisheries area, could also lead to a more quantitative ragfish density estimate but I leave that to younger computer generations.

Discussion

Ragfish are now well known from epipelagic, mesopelagic, and upper bathypelagic zones, as well as the corresponding sea bottom zones (mesobenthal, bathybenthal) (Grinols, 1965). This apparently wide-ranging depth distribution ascribed to the ragfish seems reflected in its general morphology. A relatively large mouth, soft flesh, primarily cartilageous skeleton, dark brown to chocolate black skin, narrow caudal peduncle, and broad forked tail, absence of a swim bladder in adults and generalized feeding (anything from jellyfish to rockfish), are all characteristic of a robust, active swimmer that is capable of colonizing a wide range of ecological zones.

Circumstantial evidence that ragfish readily outdistance trawls towed at 2–3 kn comes from reports of ragfish lodged in the wings of trawl nets. This inferred rapid swimming ability makes it consistent with the species' wide distribution by area and depth around the North Pacific Ocean and the Bering Sea. Thus I would expect range extensions to the Sea of Ohkotsk and off the Kamchatka Peninsula, even though Parin (1970) did not report any recoveries in those areas. Future ragfish recoveries may also come from upper mesobathyal depths, especially near the edge of sharply descending continental shelves and seamounts.

Most detailed new knowledge on ragfish presented in this paper deals with reproductive biology. The range of fecundity in the species has been enlarged and is probably now accurate for the species as a whole. By use of negative catch data from shallower-operating fisheries compared with positive catches from more deeply operating fisheries in the same areas, the potential spawning areas appear to be at least below the 120 fm (220 m) contour. Pinpointing an exact spawning location off northern California was not possible due to missing data in specimen records, but examination of egg and larvae distribution in recently published results of an early-life history investigation, targets deep channels or canyon heads as areas for future study.

Time of spawning was estimated by studying gonad morphology and maturity and mean size of eggs. Spawning time suggested in the literature, based on only a few female specimens with ripe eggs, was made more specific as the late winter-early spring period. Whether ragfish spawning behavior is social or occurs as isolated pairs or at least in small groups is not known, but females appear to discharge eggs in a single short burst suggesting mating in small groups or by isolated pairs. This might explain the current reduced number of males in samples. New ragfish recoveries having sex and size data are needed to fill our knowledge of the life history of the intermediate and smaller-sized adult ragfish. Known predators of ragfish now include species of Thunnidae, feeding on smaller specimens, with sperm whales, *Physeter catodon*, and Steller sea lions, *Eumetopias jubatus*, consuming larger adults.

Specimens known to science increased dramatically after World War II, undoubtedly due to the increase studies of oceanography, fisheries, marine biology, and higher education facilities being located along the eastern North Pacific coast. Research and educational programs that provided personnel with interest in nongame marine fishes and of species of no commercial import must also have played a role. Such contributing elements were well represented along the northern California coast. Ichthyologists such as Dan Gotshall and John Fitch working for the CDFG were just a few of past personnel working out of and through the Eureka office of the agency's Marine Resources Branch that had to influence cooperation with fishermen in landing unusual fishes for inspection.

The fact that ragfish are not only "ugly" but generally large, would also make the species somewhat susceptible for retention and donation by fishermen. Historically, however, there has been difficulty in obtaining fresh specimens from fishermen. Higgins (1921) tried but failed: "We were unable to obtain the specimen as it was sold for exhibition." Fukushima[21] reported a juvenile brought in by a vessel landing Pacific

[21]Fukushima, J. 1999. Pac. Mar. Fish. Commiss., Eureka, Calif. Personal commun.

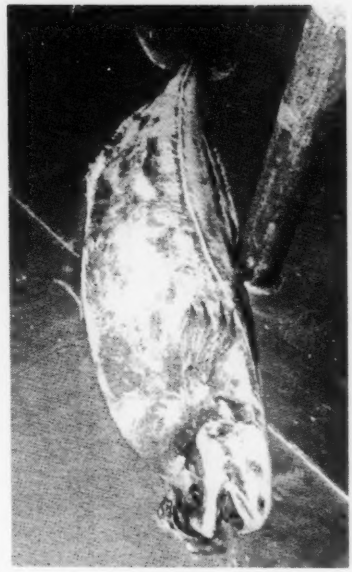

Figure 27.—Head view (left) and side view (right) of ragfish (sex unknown) showing raised lateral line of a specimen taken at assumed depth of 400 m southwest of Kodiak Island, Gulf of Alaska, 21 July 1993, by commercial trawler *Sea Fisher*. The lower gill tissues and isthmus were torn loose during handling, and the blotchy skin was probably caused by abrasions by trawl mesh. Photograph by M. Menghini.

whiting, *Merluccius productus* (Ayres), (F/V *Fishwish*, 3 August 1999) at Eureka, Calif. Its length had to be estimated from memory as about 13 in (33 cm), and it was remembered as spotted and lacking pelvics. The fisherman was not willing to donate the specimen to science as it was aesthetically pleasing to him. Indeed, beauty is in the eye of the beholder.

Many facets of ragfish biology could be approached from maintaining a facility for the long-term housing of specimens. This requires a commitment from scientists and institutions, as well as funding for large tanks and refrigeration units. For example, loss of 10–12 adult ragfish (Fig. 4A) stored in the HSU hatchery, due to a compressor failure, seriously impaired planned morphological studies. It was exacerbated because a refrigeration unit normally available for backup storage was out of commission due to a building remodel project.

Additional ragfish knowledge can likely be readily obtained from records of incidental catches extant in files of individual fisheries biologists, marine scientists, governmental agencies, and other institutions studying marine fish populations of the North Pacific Ocean. The potential in such a retrospective study was demonstrated by a chance encounter in 1999 with M. Menghini, a graduate student in fisheries at HSU. He was in consultation with a faculty colleague when, inquiring with the faculty member, I mentioned ragfish. The student volunteered his knowledge of a ragfish specimen he had encountered during July 1993 when employed as an NMFS observer on the 242 ft stern trawler *Sea Fisher* operating in the Bering Sea and Gulf of Alaska. The specimen was between 5 and 6 ft (1.5–1.8 m) in length. He mentioned seeing the crew readily eat many species of fish other than the rockfishes caught by the vessel, but the ragfish was rejected for its limpness and "ugly" look (Fig. 27). No crew member had ever seen or heard of a ragfish. Menghini vaguely recalled a supervisor commenting on the rarity of species, since the supervisor only estimated about 1 in 500 vessels reporting a ragfish in their catches.

The *Sea Fisher* had operated for two months in the Bering Sea without previously encountering a ragfish. Such a fish ordinarily would not be noted in the records since it is not a targeted species in the official samples of the catch taken and processed by observers. Nevertheless, an inquiry as to the existence of such records incidental to the required catch data is an example of the potential untapped material on ragfish I was unable to investigate for this report until the appearance of the NMFS databases.

I found another interesting correlation between the recovery of a few juvenile ragfish (13–33 cm) off Japan's Pacific coast (at the southern edge of ragfish distribution in the western North Pacific) and the four smaller specimens (29–42 cm) recorded by the NMFS research trawling off central California (Kubota and Uyeno, 1971). These data support the comments of Fitch and Lavenberg (1968, 1971) that "juveniles supposedly inhabit great depth, but fair numbers have been captured in relatively shallow water near the shore or near the surface offshore." This could be a chance correlation related to location of fishing effort. Precise information continues to be scarce for ragfish from about 5 cm to about 25–30 cm when small immature specimens begin in catches. Juvenile ragfish with their much more pronounced dentition than adults, and with lightish skin covered with irregular-shaped (blotchy) black spots appear adapted to life along or around rocky reefs or boulder piles. Such areas might lie just deep enough not to be targeted by hook-and-line sport fisheries or to be avoided by commercial fishing gear. I believe that suspended underwater video surveillance of such locations might be an initial inexpensive technique for identifying juvenile ragfish habitats, and observing a live adult.

Early literature mostly lists ragfish with "air bladder large" (Goode and Bean, 1895; Jordan and Evermann 1889; Regan, 1923); however, Günther (1887: 46) quoted a description by Jordan and Gilbert (1881) (not seen) of a small 19 cm TL specimen from San Francisco as "without air bladder." Recent language on the topic states: "gas bladder is closed" (Hart, 1973). While examining available specimens of ragfish in the HSU collection for sex, no obvious gas bladders were noted unless the structure escaped notice by being distorted or atrophied in the formalin-fixed alcohol preservative. No statements concerning the presence or absence of air bladders, or other in-

Table 13.—Data of 13 ragfish found 22 March 1999 in files of California Department of Fish and Game, Marine Resources, Eureka, Calif. (not recorded by John Fitch or HSU).

CDFG no.	Date	Location[1]	Depth (fm)	Length (cm)	Wt (kg)	Sex	Vessel
136-65	23 Sep 65	2410-2550	235				*Diana*
140-65			shallow	115		F	*Pearl Harbor*
152-66	3 Apr 66			102		F	*City of Eureka*
164-66	11 Jun 66	2365–2260	240	114		F	*Admiral King*
182-66	14 Aug 66	100 fm W Fort Bragg		juv.			Unknown
293-69	18 Mar 69	38°08'N–123°34'W	270				*Pearl Harbor*
0018-75	18 Dec 75	1H6-2900	340–350	50 TL	0.59		*Midnight Sun*
0019-75	2 Jun 75	1H6-2600	300				*Dennis Gayle*
0015-75	23 Jul 75	1H6-1800	310-320	70 FL (80 TL)	3.2		*Day Dream*
008-78	15 Aug 78	Block 2625	50–450	45 TL			*Stephanie*
0009-78	28 Aug 78	2140-2100	67	19 SL (22 TL)			*Karen Kelly*
0013-78	Sep 78	Near Crescent City, Calif.		28 SL (32 TL)	0.35		Unknown
0008-79	16 Jun 79	Off Coos Bay, Oreg.	340	81 SL (92 TL)	4.2		*Blue Max*
Number with data	12	11	10	10	4	3	11
Percent with data	92	85	77	77	31	23	85

[1]As listed on available records. Numerical descriptions are Loran C readings overprinted on U.S. Coast and Geodetic Survey charts, and CDFG marine fisheries block numbers.

ternal organs, were made in my records of female ragfish opened for removal of ovaries. Future investigations on ragfish internal anatomy could clarify this topic needed to understand ragfish depth distribution by age and size.

The bias inherent in samples from commercial gear and fishing techniques constrains the precision of results made from catch data, and this may continue to limit our understanding of distribution and life history of this fascinating and still puzzling species. Nevertheless, the fragmentary historical knowledge collected here does increase our understanding of one relatively uncommon deepwater species of fish and, more importantly, may serve as a model for additional studies on other little known or rare species as well as to stimulate more interest by marine scientists in the ragfish.

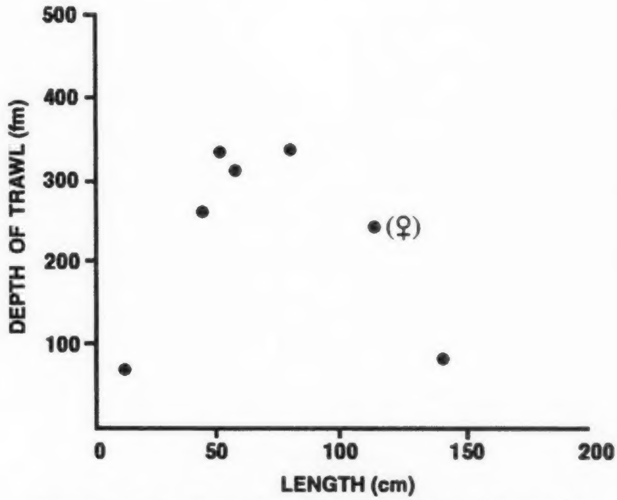

Figure 28.—Size of ragfish compared with depth of capture for specimens recorded in files of the California Department of Fish and Game, Eureka, Calif., 22 March 1999.

Ragfish Records Recovered in 1999

The challenge to incorporate highlights from the records of 621 ragfish collected by NMFS as received August 1999 has been discussed earlier. Prior to the surfacing of the NMFS data, however, there was another such late uncovering of ragfish records. These records are reported separately in this section.

During a visit with L. Quirrolo, CDFG, Eureka, Calif., to reexamine agency ragfish acquisitions, I noted ragfish records that apparently were neither in John Fitch's nor in HSU files. On further analysis of a file containing 25 records, I found 13 fish that were not previously included in the historical records (Table 13). Most of the new information was not integrated into the main text, but some data were readily incorporated into text graphs. The number of ragfish added to the historical number of specimens known to science (Fig. 4B) from this set were: three specimens each for 1966, 1975, and 1978, and one fish each for 4 years scattered throughout a 1965–79 period. Lengths of nine ragfish were also added to the graphical history (Fig. 4C). Ragfish reported caught in 1975 and 1978 were relatively small (Table 13).

The limitation in synthesizing life history scenarios from specimens provided by volunteer donors as discussed previously was also evident in the CDFG data added in 1999. In the 1999 additions, most missing data involved weight and sex (only 31% and 23% complete in these categories, respectively). This was slightly different than the analysis of records of specimens utilized in the main text where most missing information involved location (49% complete) and weight (42% complete) (see Missing Data section in Materials and Methods). A plot of depth of capture vs. size of ragfish (Fig. 28) produced a pattern of smaller fish at deeper depths, but the relationship was probably biased by a preponderance of small fish in the sample. Sex was available for only three specimens (females), all over 100 cm

in length. If the assumption were true that 50–80 cm long ragfishes not assigned a sex were either males or immature, it points to relatively deep habitats for ragfish around 50 cm in length off the northern California and Oregon coasts.

Little additional information on food habits was found in the new data. Only one specimen had a record listing stomach contents, and this was noted as empty. This again is consistent with the paucity of data on food habits as previously reported an assumption can be made that a "no comment" equates to an empty stomach.

The 13 new ragfish records showed ten different vessels contributing specimens, with two specimens coming from unknown sources. The names of the vessels and number of specimens contributed were as follows: *Pearl Harbor* (2), and one specimen each for *Diana*, *Midnight Sun*, *Dennis Gayle*, *Karen Kelley*, *Blue Max*, *City of Eureka*, *Day Dream*, *Stephanie*, and *Admiral King*. Vessels not previously recorded as catching ragfish in the new data set from northern California areas brought the total contributing vessels to 24. This examination of the 1999 data did not indicate any error or bias would occur to the analysis in the main text by not including this information, most of which came from ragfish caught in northern California fisheries.

Acknowledgments

Without the cooperation of owners, skippers, and deck hands of commercial trawlers in contributing ragfish caught off northern California ports, a major portion of this study would not have been possible. The names of these vessels along with the number of specimens contributed by each are: *City of Eureka* (7), *Admiral King* (4), *Northern Light* (3), *Jeanne Arain* (3), *Stephanie* (3), *El Pescador* (3), *Pacific Pearl* (2), *Day Dream* (2), and one specimen each from the *Franklin*, *Empire II*, *Intrepid*, *Miss Jo Anne*, *Katherine Anne*, *Sitka*, *Rainbow*, *Flicker*, *Clara G*, *El Carat*, *Ina*, *Diana*, *Midnight Sun*, *Dennis Gayle*, *Karen Kelley*, and *Blue Max*. My thanks to David Hankin for assistance with statistics and his preliminary organization of ragfish data for mathematical analysis, to James R. Gast for aid in mapping ragfish catch locations, and to Gus Thiesfield for assistance in measuring testes of male ragfish extant in HSU collection in 1999.

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Ragfish Literature

Because there are the relatively few publications, either primary or gray literature, with reports of original observations on ragfish, I hoped to compile a bibliography on the ragfish. Literature in journals with languages other than English cited by authors included in this paper were not all collected, and translations were not attempted. Publications mentioning ragfish but not containing primary material also were not included in my literature citations (i.e. textbooks, encyclopedias, distribution lists and

keys to fishes, or monographs exploring specific fields such as fish morphology, marine biogeography, and ecology). The earliest ragfish citations are in the papers by Lockington (1880) and Bean (1887), with a large segment of the Japanese literature available in Abe (1963). Russian literature was not covered, although many such citations are listed by Japanese authors. Governmental and institutional documents, other than the RACE and REFM databases sent to me in August 1999, probably contain incidental catch data on ragfish not uncovered in this literature search.

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Fishery Management and Local Communities: The Case of Madeira Beach, Florida

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Introduction

National Standard 8 of the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA) (as amended by the Sustainable Fisheries Act of 1996) requires that regulatory impacts on fishery-dependent communities be assessed. The MSFCMA defines a fishing community as a community which is substantially dependent on or substantially engaged in the harvest or processing of fishery resources to meet social and economic needs, and includes fishing vessel owners, operators, crew, and United States fish processors that are based in such communities (MSFCMA, Section 3). In addition, the National Standard guidelines (1 May 1998; 63 FR 24211) define a fishing community as a social or economic group whose members reside in a specific location and share a common dependence on commercial, recreational, or subsistence fishing, or on directly related fisheries dependent services and industries (for example, boatyards, ice suppliers, tackle shops). Sustained participation is defined to mean continued access to the fishery within the constraint of the condition of the resource (50 CFR 600.345).

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ABSTRACT—This paper uses an industrial organization approach to trace the impact on Madeira Beach, Fla., and surrounding areas of a 1-month closure of the grouper fishery from 15 February 2001 to 15 March 2001. A proposed 2-month closure is also evaluated. This approach identifies the economic relationships in the industry based on both product and place. The empirical analysis measures the losses in employment and income, information that enriches social and anthropological research on fishery-dependent communities. The 1-month closure is estimated to have reduced annual catches landed in Madeira Beach by 9.7–10.1% and annual revenues by 9.3–11.5%. These reductions are associated with a direct loss of about 33 full-time (annualized) jobs and personal income losses between $8 and 12 million in Madeira Beach and Pinellas County over a 10-year period. If the closure occurs for 2 months, annual landings and revenues will be reduced an estimated 17–21% and 20–23%, respectively.

Literature in sociology and in anthropology use various methodologies such as cultural mapping, social and cultural impact assessment, and development of classification systems to identify fishing-dependent communities. These methods are used to measure potential alteration to the relationships with the natural resource, with the local historical and cultural traditions, and to the sense of identity with the place. This literature only indirectly measures the potential alteration to economic relationships.

This research introduces the methods of industrial organization to the study of fishing-dependent communities. Industrial organization, a subfield in economics, is the study of the structure of firms and markets and their interactions within an industry. An industry is comprised of firms and employees at various levels of production and is usually defined along both product and place lines, e.g. the industry in the United States for shrimp. A market includes both demanders and suppliers and is defined along both product and place lines as well, e.g. the market in the United States for shrimp. By looking at the industry as a whole, this research attempts to measure the potential alteration to economic relationships within the market. The measures are loss of employment and income. These measures add economic relationships to the literature which includes social and anthropological relationships.

Literature Review

This section provides a brief review of the literature in sociology and anthropology which discusses fishery or natural resource related communities and methods for assessing impacts on those communities. The studies introduce various means to identify the community and various methods to assess alterations to the relationships within the communities that might result from regulations.

Kusel (1996) defines a forest-dependent community as a place with a traditional geographical sense and a measure of place identity. That is, he asks, How do people in that place relate to the natural resource base beyond economic or social measures found in the U.S. Census (e.g. population, educational achievement, poverty)? To test this approach, Doak and Kusel (1996) examined six forestry regions in California. They used community workshops to involve local expert knowledge. They began with census block groups, built up to the county level, and then they explored the levels of identity that these various groups had with particular definitions of community. One of their major findings was that socioeconomic groupings were not good predictors of community place identity.

The Pacific Fishery Management Council's website[1] presents some baseline fishery descriptions of U.S. west coast marine fishing communities. The Council defines these communities as counties where any activity occurs which is related to Council-regulated fisheries in California, Oregon, and Washington. Community data include recent and projected populations, age structure, ethnic and racial characteristics, educational attainment, employment characteristics, labor and proprietor income information, export bases, landings data, and ex-vessel revenue information.

Dyer and Griffith[2] drew on the concept of Natural Resource Community (NRC) as a basis for their definition of a fishery-dependent community. NRC's exist where individuals have dependence on a "renewable natural resource and . . . are rooted in local history and local traditions, deriving social and cultural identity from a sense of place whose life rhythms rise and fall with populations of fish, seasonal conditions at sea and the increasingly complex regulatory environment entangling their traditions."

They conducted a baseline study of New England and the Mid-Atlantic communities dependent on the multispecies groundfish fishery (MGF). The study examined the alteration of social, human, and cultural capital that would occur with a complete collapse of the MGF. Their research areas were selected using licensing data, vessel tonnage listings, permit data, and information from key informants such as state enforcement personnel, NMFS port agents, and local industry members. Additional social and economic data were collected during community visits.

To measure fishery dependence, Dyer and Griffith[2] developed a Fishery Dependence Index using measures of infrastructure and support related to fishing such as numbers of repair and supply facilities and fish dealers and processors; the presence or absence of religious and secular art and architecture dedicated to fishing; and numbers of MGF permits and vessels.

Variation in fishery dependency both between and within ports was also measured. Ports that were found to be more isolated and less flexible in terms of ability to move to other fish stocks and gear types were more fishery dependent; ports where particular classes of fishermen within the industry were not well integrated into other fisheries or economic entities (e.g. tourism) were ranked more dependent on the MGF fishery. Ports with historical and cultural indicators of reliance on fishing (mariner museums etc.) were ranked more dependent. Competition and conflict amongst participants reflected perceptions that the resource was scarce and, therefore, that the participants were more dependent on it.

Griffith (1996) categorized fishermen's dependence on resources in North Carolina by examining 1) motivation for fishing (e.g. income, recreation, subsistence), 2) percentage of income derived from fishing, 3) time commitment (months per year and total years of experience), 4) flexibility index, from low to high, measuring the numbers of gears, fisheries, and species with which the fisherman is engaged, 5) number of different kinds of vessels, 6) number of crew involved in fishing operation, 7) relationship to the seafood marketing/processing sector, 8) principal social problems, 9) principal biological issues, 10) most desired regulations, and 11) most disruptive regulations.

Using this system, fishermen were grouped into seven categories on a continuum from full-time, owner/operator commercial fisherman to affiliated recreational fisherman (angler). This classification scheme goes beyond simple ranking by income earned from the fishery and introduces economic relationships with crew and market variables. Ethnographic data such as investigations of fishermen's main social and biological concerns related to fishing contributed to an evaluation of how the various categories of fishermen would be affected by a range of proposed licensing systems. Griffith used cultural mapping of fishing locales throughout North Carolina, questionnaires, in-depth interviewing, and focus groups to identify communities. Secondary sources also were consulted, such as fishery organization membership lists and data collected by the N.C. Department of Marine Fisheries.

Wilson et al. (1998) conducted a social and cultural impact assessment of the Highly Migratory Species (HMS) Fishery Management Plan (FMP) and the amendment to the Atlantic Billfish FMP. They combined baseline descriptions of affected fishing communities with an analysis of potential impacts—both quantifiable and qualitative—on these communities. The communities were selected partly by examining landings data, but with a recognition that the fishing fleets employing particular gears are dispersed geographically.

The existence of previous studies and the suggestions of HMS and Atlantic Billfish Advisory Panels also influenced the choice of which communities were studied. The study analyzed locations in Puerto Rico, Louisiana, Florida, North Carolina, New Jersey, and Massachusetts to illustrate the range of potential impacts of the proposed regulatory changes.

Wilson et al. (1998) outlined three categories of impacts on their selected communities: 1) those which "affect the volume of money that is going through the community," 2) those which "affect the flexibility of the fishing operations," and 3) those which "impose direct costs on fishing operations." To measure social and cultural impacts, they referred to the "economic vulnerability" of the fishery in terms of competition faced in supply and marketing and the extent of social capital or community networks available. Social capital includes those aspects of a community's social structure which allow people with little financial capital "to accumulate the symbolic and material means to participate successfully in an economic activity" (Dyer and Griffith[2]). Social capital consists of trust, relationships, and support institutions such as churches and other means that enable economic capital to make necessary connections (Wilson et al., 1998).

Wilson et. al (1998) measured fishery dependence by examining demographic variables, percentage of employment in fishery related industries, income for those industries, landings by species,

[1]http://www.pcouncil.org.

[2]Dyer, C., and D. Griffith. 1996. An appraisal of the social and cultural aspects of the multispecies groundfish fishery in the northeast and the mid-Atlantic regions. A report submitted by Aquirre International to NOAA/NMFS contract 50-GNF-5-00008.

and fishing related businesses (marinas, boat rental shops, dive shops, boat dockage and repair facilities, tackle and bait shops, tourism related to fishing). They also documented the social capital of the fishing community by counting numbers of recreational or commercial fishing associations and fisherman participation in each. Wilson's study identified several fishing dependent communities along the Gulf of Mexico coast. These communities were designated as dependent on the billfish fishery.

McCay[3] suggested that assessments of regulatory impacts on fishing-dependent communities consider not only geographic definitions of communities and economic characteristics therein, but also the level of vulnerability or resilience of fishing communities and operations. That is, questions of fishing dependence and "sustained participation" in fisheries must consider how able participants in a given fishery are to move among fishery sectors, and how able they are to move out of the fishery altogether and into other employment opportunities.

In summary, many of these studies used economic data such as landings, numbers of vessels, license information, and employment characteristics to identify the location of the community under analysis (e.g. Griffith, 1996; Wilson et al., 1998; Pacific Fishery Management Council[1], Dyer and Griffith[2]).

Once a location is identified, the second stage is measuring fishing dependency. The dependency is measured as social, psychological (identity), and/or economic. Economic dependency refers to economic vulnerability or ability of fishermen to find alternative employment given the social and physical capital of the area.

This paper uses data collected by the State of Florida for a particular industry and market. The industrial organization analysis traces the fish through the market system by product type and identifies the groups that would be impacted by a regulatory action. The approach recognizes that a particular species may be landed in one location, sold in another, and consumed in even another. The participants in the market flow are harvesters, wholesalers, and retailers as well as consumers—all part of the industry.

Each fish species may be part of a unique economic group or industry depending on the product market in which it is sold (i.e. fresh vs. frozen, packaged, smoked, dried, restaurant, or institutional consumption). Measuring the fishery dependence of the group or community then includes identifying substitutes not only in production but in consumption; not only in one location but through the product market. This type of analysis has the potential to show clearly where the economic dependency occurs—in a place or in a market.

This paper looks at only two types of measurable loss from regulations: employment and income. The losses are attributable to particular locations. This information on economic relationships together with social and anthropological relationships develops a more complete picture of community. Future research using this approach might look at other related variables, such as loss of capital by vessel owners or gains to those who catch the substitute species as economic relationships become altered because of a regulatory action.

Informed by the earlier studies on fishery-dependent communities, Madeira Beach, Fla., and the grouper industry were the selected site for analysis because of economic importance (over $6 million annual ex-vessel value) and because the fishery closure in 2001 provided an opportunity to collect data on economic relationships in the industry to measure potential losses.

The commercial harvesting sector in Madeira Beach includes vessels with bottom longline, hook and line, and bandit rig (hook and line) gear (Cato and Prochaska, 1997). These vessels catch several species of grouper (Serranidae) and shark (Lamniformes). The wholesale sector of the industry includes fish houses which broker fish and provide services to the vessels such as transportation, accounting, fish filleting, and sales to other wholesale outlets and retailers. Other firms in Madeira Beach provide maintenance, gear, bait, ice, groceries, and supplies. The retail sector includes grocery stores and restaurants, either specialized in seafood sales or in general food sales.

The research here is preliminary in the sense that we do not consider cumulative effects on this industry from regulations on swordfish (Xiphiidae) and sharks which affect the same reef fish industry. Earlier impacts on the City of Madeira Beach and its fishing activity are described in the FMP for Highly Migratory Species (USDOC, 1999). This FMP says "Nevertheless, NMFS is aware that the cumulative impacts of shark measures in this FMP may put some fishermen out of business and result in a permanent loss of community infrastructure in Madeira Beach" (USDOC, 1999:70).

This research also does not consider the effects of imports on the market, fluctuations in demand, or certain ethnographic relationships in the market. Antozzi (2001) documents a 246% increase in fresh snapper (Lutjanidae) imports to the U.S. between 1991–2000, predominantly from Mexico, Panama, and Brazil. He also shows a 155% increase in fresh grouper imports for the same period from Mexico, Panama, and Columbia. These imports are probably substitutes in consumption for grouper products currently caught by U.S.-based fishermen. Import substitutability may be of particular importance in this market and deserves attention inasmuch as it reflects altered economic relationships.

Background Regulations and Data

The grouper fishery is managed under the Reef Fish Fishery Management Plan passed in 1984 by the Gulf of Mexico Fishery Management Council. This fishery has had a permit moratorium since May 1992.[4]

Grouper are managed as one unit for recreational catches and as two units (shallow water and deep water) for commercial harvest. Shallow-water grouper include red, *Epinephelus morio*; gag, *Mycteroperca microlepis*; black, *Mycteroperca bonaci*; yellowfin, *Mycteroperca venenosa;* yellowmouth, *Mycteroperca*

[3]McCay, B. J. 2000. Defining community: a fisheries perspective. Presentation at the annual meeting of the American Anthropological Association, San Francisco, 15–19 Nov. 2000.

[4]The moratorium allows transfer of permits between vessels. Fish dealers are also required to have permits to handle grouper and may buy only from permitted vessels.

Table 1.—Commercial grouper catches and value for the west coast of Florida, 1996–99 by species.[1]

Species	1996		1997		1998		1999	
	Pounds	Ex-vessel value ($)	Pounds	Ex-vessel value ($)	Pounds	Ex-vessel value ($)	Pounds	Ex-vessel value ($)
Black grouper	443,790	1,000,266	283,651	620,596	292,632	648,620	312,106	703,525
Gag	1,481,641	3,474,761	1,657,075	3,837,629	2,718,533	6,309,071	2,129,664	5,052,567
Misty	1,229	1,826						
Nassau	798	1,163						
Other grouper	4,561	7,059	4,281	6,715	6,832	11,999	9,773	19,298
Red	5,274,922	9,871,816	5,765,110	10,497,403	4,680,358	8,705,411	17,016,621	13,163,410
Scamp	231,133	556,094	255,768	600,664	220,756	509,195	225,346	537,239
Snowy	112,344	209,893	184,253	352,071	130,148	252,809	168,243	333,068
Warsaw	21,869	33,463	36,363	54,771	30,164	48,715	68,014	117,484
Yellowedge	399,652	897,104	702,300	1,555,649	564,218	1,292,903	814,495	1,913,605
Yellowfin	12,159	24,643	1,769	3,575	297	647	441	861
Total	7,984,098	16,078,088	8,890,570	17,529,073	8,643,938	17,779,370	10,744,703	21,841,057

[1] Source: Personal communication from the National Marine Fisheries Service, Fisheries Statistics and Economics Division, Silver Spring, Md., Jan. 2001.

interstitialis; rock hind, *Epinephelus adscensionis*; red hind, *Epinephelus guttatus*; and scamp, *Mycteroperca phenax*. Deepwater grouper include misty, *Epinephelus mystacinus;* snowy, *Epinephelus niveatus;* yellowedge, *Epinephelus flavolimbatus*; warsaw, *Epinephelus nigritus*; speckled hind, *Epinephelus drummondhayi*; and scamp (after the shallow-water quota is filled). Protected grouper species are goliath, *Epinephelus itajara*; and Nassau, *Epinephelus striatus* (GMFMC[5]). There are minimum length size requirements and recreational bag and size limits which vary by species. There are two marine reserves established on gag grouper spawning aggregation sites that are closed year-round to all fishing. The sites are off west central Florida and cover 219 n.mi.^{2} near the 40-fathom contour (GMFMC[6]).

Grouper worth more than $31 million ex-vessel value (almost 15.5 million pounds) was landed in Florida coastal areas in 1999. In 1999, over 6 million pounds were landed in Pinellas County on Florida's west central coast, valued at almost $12 million (Florida Fish and Wildlife Commission[7, 8]).

Historical grouper catches for west Florida by species are given in Table 1 for 1996–99. The west coast includes all of the landings areas from the Florida panhandle south along the coastline. Of the 11 categories of grouper, red grouper are the most valuable with gag grouper the second most valuable in total landings. Over $21 million in grouper were landed by the commercial fishing fleet along this coast with the rest (about $10 million) landed on the east coast of Florida. East coast landings are managed by a different management council.

Table 2 lists average ex-vessel nominal prices for several species for 1993–2000. Average nominal grouper dockside prices in 2001 on the west coast of Florida at the ex-vessel level were $1.90–$3.10 for red grouper; $2.40–3.60 for black grouper; $2.40–3.60 for gag, warsaw, and other types of grouper. Between 1993 and 2000, grouper prices moved up and down without a clear trend. The range of nominal grouper price increases in those years is between –1% and +12% annually. In other years prices increased between 2 and 6%.

Some studies on the recreational sector operating in the Gulf of Mexico identified particular ports and locations where the fishing activity occurred, but this information is not available for the commercial sector. (Ditton et al., 1992; Holland et al., 1992; Sutton et al.[9]). Within Pinellas County, there are two cities where large

Table 2.—Average nominal ex-vessel prices for grouper landed on the west coast of Florida, 1993–2000.[1]

Year	Average ex-vessel price[2] of grouper	Real prices[4] (1982=100)
1993	1.72	1.45
1994	1.82	1.51
1995	1.80	1.44
1996	1.92	1.50
1997	1.98	1.55
1998	2.06	1.66
1999	2.10	1.67
2000	2.35[3]	1.77

[1] Source: Calculated from data obtained from personal communication from the National Marine Fisheries Service, Fisheries Statistics and Economics Division, Silver Spring, Md., Jan. 2001.

[2] Prices are unadjusted and averaged across these species: gag, black, nassau, red, snowy, warsaw, yellowedge, yellowfin, scamp. Actual price ranges for 2001 were $1.90–3.10 for red grouper, $2.40–3.60 for black grouper, $2.40–3.60 for other species.

[3] Preliminary.

[4] Seasonally adjusted with producer price index. Base year = 1982.

amounts of grouper are off loaded: Madeira Beach and Tarpon Springs, and Madeira Beach landings are about 70% of the county total. Table 3 lists commercial grouper landings in Pinellas County by species for 1996–99.

Analysis is based on several sources of data. Fish dealer reports (trip tickets) are required for this fishery by the State of Florida and include information from reef fish dealer permit holders. This

[5]GMFMC. 1999a. Regulatory amendment to the Reef Fish Fishery Management Plan to set 1999 gag/black grouper management measures (rev.) Aug. Gulf Mex. Fish. Manage. Counc., Tampa, Fla.

[6]GMFMC. 1999b. Amendment 17 to the Reef Fish Fishery Management Plan for the Reef Fish Resources of the Gulf of Mexico. Sept., Gulf Mex. Fish. Manage. Counc., Tampa, Fla.

[7]Eastern Gulf of Mexico is defined as the Gulf coast of Florida from Franklin County (Apalachicola) to Collier County (Everglades City).

[8]Commercial Fisheries Landings in Florida data available online at the Florida Fish and Wildlife website at http://www.floridamarine.org/features/view_article.asp?id=19224.

[9]Sutton, S. G., R. B. Ditton, J. R. Stoll, and J. W. Milon. 1999. A cross-sectional study and longitudinal perspective on the social and economic characteristics of the charter and party boat fishing industry of Alabama, Mississippi, Louisiana and Texas. Rep. by Human Dimensions of Recreational Fisheries Research Laboratory, Texas A&M Univ. for NMFS. MARFIN program grant NA 77FF0551.

Table 3.—Commercial grouper landings in Pinellas County by species, pounds, ex-vessel value, 1996-99.[1]

	1996		1997		1998		1999	
Species	Pounds	Ex-vessel value ($)	Pounds	Ex-vessel value ($)	Pounds	Ex-vessel value ($)	Pounds	Ex-vessel value ($)
Black	83,446	217,544	130,287	341,222	197,216	521,636	209,621	565,348
Gag	578,071	1,574,087	536,880	1,485,547	917,525	2,547,049	835,138	2,361,770
Misty	329	725	808	1,752	408	991		
Nassau	2	3						
Other	34,529	57,905	48,794	103,687	43,625	90,785	52,431	112,307
Red	2,665,142	5,764,702	2,848,077	6,120,517	2,718,376	5,969,554	4,154,947	9,190,743
Scamp	89,032	244,482	101,302	279,897	107,560	296,220	108,943	308,418
Snowy	33,186	72,777	72,358	160,707	46,065	105,811	72,311	170,365
Warsaw	13,110	23,270	10,541	18,731	10,538	20,123	13,742	27,979
Yellowedge	137,900	360,746	313,503	819,183	286,925	776,133	338,397	938,713
Yellowfin	1,232	2,942	1,073	2,415	118	311	189	469
Total	3,635,979	8,319,183	4,063,623	9,333,658	4,328,356	10,328,616	5,785,719	13,676,112

[1] Source: Florida Fish and Wildlife Commission, reported commercial landings as of 24 July 2000; 1999 is preliminary.

source provided landings and revenues by species and were obtained with dealer permission from the Florida Marine Research Institute (FMRI) for 1999 and 2000. These data were aggregated across dealers located in Madeira Beach and supplemented by firm settlement sheets. Firm settlement sheets are business receipts which record date of transaction, types of fish bought from particular vessels, price, poundage, and type of vessel. Other settlement sheets record monthly sales of bait, ice, groceries, and other supplies from dealers to vessels. These sheets enabled us to estimate the numbers of vessels, by type of gear used, which off loaded at Madeira Beach dealers in an average year. Through interviews with key informants in the industry, we were able to identify and estimate the number of restaurants and wholesalers which were buying from the Madeira Beach dealers.[10] The study relies heavily on the results of the 1994 Waters[11] survey of the same fishery for vessel characteristics which asked about costs, demographic and economic characteristics in the fishery for 1993. A later survey by Waters[12] provided updated catches and revenues from logbook data as of 11 April 2001. All of the estimates of impacts of the closures used trip ticket data and firm settlement sheets.

Additional data were collected in onsite interviews with fish dealers, vessel captains and crews, restaurant owners, and supplier firms. The interview period was October 2000–March 2001. Income and demographic data were obtained from the Pinellas County Economic Development Office, the U.S. Census Bureau, the Madeira Beach Chamber of Commerce, and the Gulf of Mexico Fishery Management Council. The impact analysis was run through the REMI (Regional Economic Models, Inc)[13] model for Pinellas County and west central Florida maintained by the Tampa Bay Regional Planning Council.

Industrial Organization of the Market

Madeira Beach, Fla., is at the top of the list of places where grouper are off-loaded in the Gulf of Mexico. This is the center of the production for this study. From this center, we trace the fish along industry lines to discover economic relationships that depend on this center. Thus we can partially measure fishing dependency as the loss in employment and income when the center activity is altered.[14]

Madeira Beach, where the fish are landed, is in Pinellas County, on the west central coast of Florida, between two much smaller fishing communities: Cortez, about 2 h south by sea in another county, and Tarpon Springs, about 3–4 h north by sea in Pinellas County. Fewer and smaller boats off-load in Cortez and Tarpon Springs, which are farther than Madeira Beach is from metro area final sales and distribution markets. Pinellas County is the fourth most populous county in the state with a population of 921,482 (U.S. Census Bureau[15]).

Madeira Beach, incorporated in 1947, now has a resident population of 4,409. About 5,000 additional winter residents also live there part of the year. The top four economic sectors in Madeira Beach are retail trade, $61.5 million in annual receipts; accommodations and food services, $16.8 million in annual receipts; wholesale trade, $13 million in annual receipts; and administrative and support, $12.3 million in annual receipts (U.S. Census Bureau[15]).

[10]We did not track sales of dealers established outside Madeira Beach. There are dealers who may send a truck to buy fish from vessels ported in Madeira Beach. Their sales are not included in this analysis.

[11]Waters, J. R. 1996. An economic survey of commercial reef fish vessels in the U.S. Gulf of Mexico. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Beaufort, N.C., 63 p.

[12]Waters, J. R. 2001. Various tables prepared for the Gulf of Mexico Fishery Management Council on Grouper Landings in the Gulf of Mexico. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Beaufort, N.C.

[13]REMI model has all the inter-industry relationships that are in an input-output model in the output block and also includes data sets from the Tampa Bay and State of Florida regions to estimate key economic relationships such as the relationships between population and labor supply, labor and capital demand, and market shares. Expenditures in a particular sector can be entered and the output shows employment impacts by sector (e.g. mining, construction) as well as impacts on personal income by sector, changes in the labor force, and wage rates over time. Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

[14]This study is partial because the analysis measures losses from first level impacts only. That is, rather than relying on the REMI model to calculate losses beyond the first level, had budget permitted, we could have calculated and identified losses in the wholesale and retail levels as well.

[15]United States Census. 2000. State and County Quick Facts from the U.S. Census Bureau web: http://quickfacts.census.gov/qfd/states/2000.html.

The business profile of Madeira Beach includes 52 restaurants, 1 casino ship, 3 marinas, 30–40 charter vessel operations, and 396 condos, hotels, and rental units. Hotels and motels are scattered along the gulf side of the city, and restaurants and homes are along the intracoastal side. Businesses are related to tourism, fishing, and Gulf of Mexico activities. The average household size is 1.8 persons. There is a 70.9% owner occupied ratio, with the median household income at $35,247, which is slightly lower than the median household income of Pinellas County at $35,904 and slightly higher than the U.S. median household income of $34,067. Waters' 1994 survey[10] found the median income of fishermen to be $30,000.

Summary data from Waters[11, 12] for the vessels in the reef fish fleet, which includes the grouper vessels, are given in Table 4. Estimated total value for vessels fishing the eastern Gulf of Mexico for reef fish in 1993 exceeded $26 million using average values. The average trip hired 2–3 crew members and stayed at sea 10–14 days. Trip costs varied by gear type and vessel productivity, and ranged between $298 and $2,942 per trip. Survey respondents had an overall average age of 47 years with most in the 40–49 year age group. Very few were younger than 30. Almost all of them had a high school education. Respondents averaged about 44% of household income from commercial fishing for reef fishes and 21% from other types of commercial fishing. Respondents averaged 19 years fishing experience (Waters[11]).

Based on firm settlement sheet data collected from market participants, there were an estimated 87 bottom longliners and at least 48 bandit rigged/vertical line vessels homeported in Madeira Beach. Vessel distribution is given in Table 5.

Table 4.—Economic characteristics of reef fish vessels fishing for reef fish on the west coast of Florida, 1993 (unadjusted dollars).[1]

Gear type	No.	Estimated total value of vessels (Million $)	Range of average annual net income[3, 4] (1,000 $)	Range of routine costs per trip[2, 4]	Range of average no. trips per year[4]	Range of average no. days per trip[4]
Vertical hook and line	339	13.98	23.8–4.5	840–298	17–18	7.9–3.0
Bottom longline	132	8.75	25.4–15.0	1955–1785	14–15	12.0–10.2
Fish traps	71	3.67	21.0–19.0	726–584	11–32	4.6–4.1

[1] Source: Waters (text footnote 10): 9, 42–45, 65 (Tables 3, 4, 12, 13, 14).
[2] Routine costs and average net income depend on volume caught and length of trip which varies both by gear and within gear type. The ranges presented are the ranges of averages of high volume (top 75%) and low volume (bottom 25%) of vessels.
[3] Before taxes.
[4] High volume-low volume.

Table 5.—Vessels and employment for grouper vessels in Madeira Beach, 1999-2000.[1]

	Vessel size			Crew size		
Gear type	<36ft	36-49ft	>49ft	Average	Total[2]	Total vessels
Bottom longliner	2	52	33	3.5	305	87
Bandit	14	34	0	2	96	48
Dealer employees					40	
Total estimated employment					441	

Total vessels regularly offloading grouper in Madeira Beach = 135
Total vessel employment = 323
Total employment = 441

[1] Source: Firm records.
[2] Includes captains

Table 6.—Estimated annual vessel routine costs by type of vessel off loading in Madeira Beach, Florida and size for 1999–2000.[1]

Boat category	No.	Fuel	Bait	Ice	Salt	Maintenance and gear	Total
Bottom longliner <36'	2	N.a.					
Bottom longliner 36–49'	38	6,037	4,870	2,582	438	10,000	23,927
Bottom longliner >49'	30	5,955	11,014	4,082	461	14,520	36,032
Bandit rig <36'	12	2,400	801	1,272	10	6,000	10,483
Bandit rig 36–48'	27	N.a.	232	982	10	8,796	N.a.

[1] Source: Firm settlement sheets and captain interviews.

These vessels employ about 305 fishermen, including crew and captains, who are supported by about 40 office and processing workers. Direct industry annual employment on vessels and in fish dealerships is estimated at 441 for 1999–2000 in Madeira Beach. Fish dealership employees work in the office, unload vessels, process fish, and transport fish (firm settlement sheet data). Indirect employment related to grouper catches is found with wholesalers, transportation firms, restaurants, and specialty and general groceries. We did not count this indirect employment with wholesalers and restaurants but allowed it to be calculated by the REMI model. In the 52-sector REMI model, there are linkages between this sector (agriculture, forestry, and fishery services) of the economy and government, construction, transportation, public utilities, financial, insurance, and real estate sectors of the regional economy.[16]

Table 6 lists estimated annual vessel expenditures by type of vessel and size for 1999–2000. These estimates come from interviews with captains, crew members, and from vessel expense receipts. The vessels catching grouper have routine costs for items such as fuel, bait, salt, groceries, and ice. For bait, the grouper fishermen typically use herring (Clupeidae) ($0.39/lb), squid (Loliginidae and Ommastrephida) ($0.49/lb), or mullet (Mugilidae) ($0.25/lb) and always buy it because the opportunity cost of catching it themselves is too high. Fuel expenditures have a much larger cost ranging from 300 to 1,000 gal per month ($2,400–6,000/year). Boat owners in Madeira Beach do much of their own maintenance and repair work. They use local repair shops for major overhauls and parts purchases. They estimate average costs of maintenance and gear for bottom longline vessels at $1,000 per month and for bandit gear vessels at $733 per month. Larger bottom longliners (>49 ft) have slightly higher maintenance and gear costs ($14,520/year) compared to

[16] These are respectively NAICS industry codes: 44-45, 72, 42, 56.

Table 7.—Monthly percentages of dockside revenues for red grouper or gag or black grouper caught with bottom longlines or buoy lines in the Gulf of Mexico, logbook data as of 11 April 2001.[1]

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1993	3.5	4.2	5.9	9.9	8.6	9.6	9.1	8.7	11.0	9.9	9.9	9.8	100.0
1994	6.4	12.5	10.8	7.3	7.6	9.1	7.4	7.7	8.0	7.6	6.4	9.1	100.0
1995	8.8	9.2	7.8	6.9	5.7	4.7	7.6	9.0	9.6	7.7	13.2	10.0	100.0
1996	8.4	9.6	6.1	8.0	7.0	7.6	5.9	6.9	8.6	7.2	12.0	12.7	100.0
1997	10.7	8.3	8.9	7.4	9.2	8.0	7.5	7.1	7.4	7.4	8.4	9.8	100.0
1998	9.5	8.4	9.1	9.5	9.3	8.3	7.4	6.9	4.8	6.7	9.3	10.9	100.0
1999	9.5	7.7	13.6	8.8	7.4	9.2	7.9	8.8	3.2	8.7	7.9	7.3	100.0
2000	9.0	8.4	11.2	8.8	10.1	5.5	4.3	3.1	3.4	12.9	11.7	11.6	100.0

[1] Source: Waters (see text footnote 11).

smaller longliners (36–49 ft) at $10,000/year. Bandit-rigged vessel maintenance and gear costs range from $6,000/year for vessels < 36 ft to $8,796 for vessels 36–48 ft (key informant interviews; firm settlement sheet data). Based on other estimates, labor costs for longlining vessels are about 32% of total costs and sales expenses are 4% of total costs of the vessels (Porter et al., 2001:67).

Historically, there have been several fish dealers in Madeira Beach. During 1999 there were four fish houses, which bought almost 100% of the grouper and shark. One dealership closed between August 2000 and January 2001 when it was reopened by a new owner. In the interim, many of the vessels off-loaded their catches at the other dealers in Madeira Beach or sold to dealers who sent trucks to the area.

Fish dealers in Madeira Beach have costs attached to buying and reselling the fish including shipping costs which have several components in addition to labor: cardboard boxes at $1.48 per box without a liner bag and $1.60 with a liner bag, wooden boxes at $3.00 per box, and truck and air freight charges. Almost all the truck services and drivers used in Madeira Beach are local, and the specialized shipping boxes are made in Avon Park, Fla.

Dealers provide vessels with a variety of services such as off-loading, moorage, and transportation at a flat rate per pound of fish. This rate is typically around 7% of the ex-vessel price which is consistent with other studies which show the following costs as percentages of total costs for longliners: dry-dock, 2%; moorage, 1%; insurance, 3%; and bookkeeping, 1%. Adding these costs to routine costs in Table 6 puts between $6.4 and $7.7 million in annual direct expenditures into the Madeira Beach economy from the reef fish fleet.

There is vertical integration in this industry and differentiation of services offered by dealers in Madeira Beach. At least one dealer owns vessels, while another is integrated into seafood retail sales in restaurants. Yet another dealer sells to out-of-region markets in Chicago and New York, while another fillets about 90% of the catch off loaded to his dealership and sells to local restaurants. Another dealer specializes in sales to upscale restaurants in the area. One dealer has ownership interests in tackle replacement and repair. One market participant said that some species sell better in various locations such as deepwater grouper in the Canadian market (market participant interviews, 2000).

This integration and specialization is commonly observed in fisheries in various parts of the world. For example, canneries may own vessels or purchase catch on a contractual basis, and provide services such as bookkeeping, docking, and unloading. These contractual economic relationships typically smooth price fluctuations for consumers as well as for fishermen.

The area of the west coast of Florida around St. Petersburg and Tampa is well known for its grouper products. About 70% of all grouper landed in Madeira Beach is consumed within 40 miles, while 30% is "exported" to other parts of Florida, out of state, and a small percentage to Canada. The value added from ex-vessel to wholesale in this industry is about 20% with about another 55–75% value added from wholesale to retail depending on species (Hamilton et al., 1996). The fish dealers in Madeira Beach sell to at least 200 local restaurants and to >24 wholesale distributors who resell to additional retail outlets. There are 26 other fish dealers permitted for grouper in Pinellas County besides those located in Madeira Beach (interviews; firm settlement sheet data, 2000). There are two major fish processors and a major fish distributor within a 30 min drive of Madeira Beach who buy and process fish for large retail buyers such as grocery stores and restaurant chains. The processing is low value-added such as filleting. The largest restaurant distributor in Florida, located south of Bradenton (Manatee County), distributes fish and seafood throughout Florida.

According to the market participants, prices are affected by supply, local tourist demand fluctuations, and the prices of close substitutes for grouper. The fluctuations in monthly percentage of revenues and landings of red and black grouper caught with longlines and with vertical gear in the Gulf of Mexico are given in Tables 7–10. The highest prices are often in spring and late fall during the tourist season but fluctuate over years and by gear. Without a full demand analysis, it is not clear which drives market prices more, demand or supply in a particular month.

In this market, there are a number of restaurants which specialize in serving grouper sandwiches or other grouper preparations on their menus. Some restaurant chefs claim that locally caught grouper has particular properties desired by their customers. These properties relate to texture and taste which consumers believe make grouper a "better eating" fish than others that might be considered substitutes. Local restaurants prefer shallow-water grouper which they say satisfies their customers. When asked what might be a substitute in consumption, no one could offer an idea. Several chefs and restaurant and grocery opera-

Table 8.—Monthly percentages of pounds landed for red grouper or gag or black grouper caught with bottom longlines or buoy lines in the Gulf of Mexico, logbook data as of 11 April 2001.[1]

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1993	3.4	4.1	5.3	8.8	8.7	11.6	10.0	8.9	10.6	9.6	9.3	9.8	100.0
1994	5.9	11.5	9.6	6.7	8.8	10.7	8.0	7.7	8.1	7.5	6.2	9.2	100.0
1995	7.8	7.9	6.6	6.1	5.7	5.4	8.7	9.1	9.5	6.8	13.2	13.2	100.0
1996	8.2	9.8	5.8	7.1	7.0	8.8	6.5	6.8	8.3	6.8	12.3	12.8	100.0
1997	9.7	8.3	8.1	6.5	10.4	9.6	8.4	7.0	7.3	7.4	7.5	9.8	100.0
1998	8.6	8.0	8.0	8.4	9.3	9.4	7.9	7.1	4.7	7.3	9.0	12.4	100.0
1999	8.6	8.6	12.8	8.7	7.7	10.9	8.4	8.8	3.1	7.7	6.8	7.8	100.0
2000	8.9	7.8	10.3	7.9	10.2	6.7	4.9	3.5	3.7	13.0	11.9	11.1	100.0

[1] Source: Waters (see text footnote 11).

Table 9.—Monthly percentages of dockside revenues for red grouper or gag or black grouper caught with vertical lines in the Gulf of Mexico, logbook data as of 11 April 2001.[1]

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1993	4.8	4.8	7.6	10.2	12.7	9.0	10.0	8.2	9.0	7.0	8.7	8.1	100.0
1994	7.3	7.6	10.9	10.3	9.0	8.4	8.8	9.1	9.1	6.5	5.7	7.2	100.0
1995	7.7	6.7	8.6	7.4	10.0	8.5	8.4	7.0	6.0	7.2	13.7	8.9	100.0
1996	9.1	10.2	5.4	9.2	9.2	7.8	5.6	6.7	7.4	8.6	9.9	10.9	100.0
1997	10.0	7.4	11.2	7.8	11.4	8.2	8.5	7.8	7.3	5.7	7.8	6.8	100.0
1998	10.4	7.8	9.1	7.8	9.4	6.7	6.2	5.3	6.2	12.5	11.1	7.4	100.0
1999	9.7	7.6	12.1	10.1	10.0	7.2	8.3	7.9	5.9	6.5	8.2	6.3	100.0
2000	6.4	7.2	8.9	8.1	11.2	8.3	6.6	7.2	6.7	12.1	7.9	9.4	100.0

[1] Source: Waters (see text footnote 11).

Table 10.—Monthly percentages of pounds landed for red grouper or gag or black grouper caught with vertical lines in the Gulf of Mexico, logbook data as of 11 April 2001.[1]

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1993	4.7	4.6	7.0	9.2	12.7	10.4	10.9	8.6	8.9	6.9	8.1	7.8	100.0
1994	6.4	7.0	9.5	9.5	9.9	9.7	9.8	9.3	9.6	6.5	5.6	7.2	100.0
1995	6.8	5.7	7.4	6.5	10.2	9.6	9.9	7.4	6.1	6.2	13.2	11.0	100.0
1996	8.8	10.3	5.3	8.4	9.2	8.8	6.1	6.8	7.5	8.0	10.2	10.8	100.0
1997	9.3	7.3	10.2	7.1	12.2	9.5	9.9	8.0	7.2	5.7	7.0	6.5	100.0
1998	9.6	7.4	8.2	7.1	9.5	7.5	6.7	5.6	6.1	13.0	10.9	8.3	100.0
1999	8.8	8.2	11.1	9.9	10.4	8.4	9.2	8.3	6.0	5.9	7.3	6.6	100.0
2000	6.0	6.4	7.8	7.2	10.8	10.0	7.7	8.4	7.4	11.8	7.7	8.9	100.0

[1] Source: Waters (see text footnote 11).

tors suggested that red snapper might be a substitute, but that it was now difficult to get under the existing regulations. Grouper has a clear cultural value on the west coast of Florida, but there are no published estimates of the cross elasticity of demand between grouper and other available species or of the determinants of demand.

This description of the market for the grouper landed in Madeira Beach includes a number of economic variables for each level of the industry: harvesting, wholesale, and retail. With the industrial organization approach it is important to describe all levels of the industry and to identify the flow of the product and the economic relationships at each level of the market. For the empirical analysis in the next section, the research used the data from the harvesting level to derive the losses in employment and income for the whole market area.

Economic Impact of a 1- and 2-Month Closure

The closure of the fishery from 15 February–15 March 2001 was the proposed management alternative adopted by the Gulf of Mexico Fishery Management Council in 1999 to be effective in spring of 2001 (Schirripa et al., 1999; GMFMC, 2001, 2002). The rationale was to provide some protection for spawning gag, red, and black grouper.

To trace the economic impacts of the closure in 2001, we used the industrial organization analysis from the previous section to direct the empirical calculation of lost employment and income. The landings data from the Madeira Beach vessel trip tickets were broken down by gear type and are presented in Table 11 for 1999 and in Table12 for 2000. Using 2,000 catches during the 15 February–15 March period, the fleet would have lost 9.8% of catch and 11.1% of revenues from a 1-month closure. The 2000 landings are lower in part because one of the dealers died in August 2000, and the dealership did not reopen until January 2001. Not all of this dealer's catch was tracked to Madeira Beach.

To evaluate the direct and indirect impacts of a 1-month, a 2-month, and a complete closure on Madeira Beach and the impacted community, the lost revenues were run through a regional economic model. Direct impacts are those which are felt by the first level of the industry such as fishermen, dealers, and vessel owners. Indirect impacts are those which come about as a consequence of direct impacts. For example, when a fisherman loses a job, the grocery store where he/she buys food would feel an indirect impact from his/her reduction in spending.

The REMI model was run by the Tampa Bay Regional Planning Council

in Tampa, Fla. The model incorporates the economic history of the west central Florida area by county from 1969 to the present. A standard REMI model can have as many as 53 industries, 94 occupations, 25 final demand sectors, and 606 age/gender/racial cohorts linked by economic relationships. After the policy is entered (reduction in fish catch and revenues), the model solves for the resulting impact on various variables such as employment, prices, relative prices, wages, and population. All of the estimates reported here are based on entering into the model only losses directly experienced by the vessel owners, crew, and dealers in Madeira Beach. There are indirect impacts that would occur but which are not included here as losses. These might include job losses to restaurants, bait or tackle shops, or maintenance facilities.

The results from the REMI simulation for the 1-month closure using 1999 and 2000 data are given in Table 13. If the closure occurs for 1 month, 15 February–15 March, and remains in effect, the industry will lose between 232,002 and 278,789 pounds of catch valued at between $613,119 and $640,724. This closure is associated with the loss of 33 jobs annually and 319 jobs over a 10-year period. The 1-month closure results in personal income losses of around $1 million per year in Pinellas County and totals $10.4 million over a 10-year period (Table 14). Statewide, job losses from a 1-month closure for the 10-year period are 343, and personal income losses are over $12 million.

The results from the REMI simulation for a 2-month closure for the period 15 February–15 April, using 1999 and 2000 data, respectively, are given in Table 14. If the closure occurs for 2 months and remains in effect, the industry will lose landings between 412,615 and 620,831 pounds valued at between $1,159,529 and $1,474,036. The 2-month closure is associated with the loss per year of about 70 jobs and over $1.5 million in personal income. Over 10 years in Pinellas County, 671 jobs and $21.6 million in personal income are lost (Table 14). Statewide, losses for the 10-year period from a 2-month closure are 721 jobs and $26.1 million in personal income.

Table 11.—Commercial grouper catches and revenues by gear type landed in Madeira Beach, 1999.[1]

Gear	Shallow-water species[2] Catch (lb)	Shallow-water species[2] Revenue ($)	Shallow-water species[2] Ex-vessel price ($)	Deepwater species[3] Catch (lb)	Deepwater species[3] Revenue ($)	Deepwater species[3] Ex-vessel price ($)
Bandit	45,415	112,050	2.47	1,338	1,764	1.32
Closure[4]	3,355	7,801	2.33	24	60	2.50
Longline	2,377,839	5,399,025	2.27	62,565	162,555	2.60
Closure[4]	239,472	521,614	2.18	3,559	7,954	2.23
Hook and line	261,970	646,199	2.46	2,237	4,796	2.14
Closure[4]	17,142	41,943	2.45	8	18	
Unknown gear	98,056	239,704	2.44	9,257	20,866	2.25
Closure[4]	14,631	32,282	2.21	0	0	0
Dive	12,251	31,369	2.56			
Closure[4]	598	1,447				
Total						
All gear	2,795,531	6,428,347	2.32	75,397	189,981	2.52
Closure[4]	275,198	605,087		3,591	8,032	2.24
Closure percent of yearly	9.8%	9.4%				
All gear, shallow and deep species combined	2,870,928	6,618,328	2.31			
Closure[4]	278,789	613,119	2.20			
Closure percent of yearly	9.7%	9.3%				

[1] Source: Florida Fish and Wildlife Commission and Madeira Beach dealer trip reports.
[2] Shallow-water groupers includes red, gag, black, yellowfin, yellowmouth, rock hind, red hind, scamp.
[3] Deepwater grouper includes misty, snowy, yellowedge, warsaw, speckled hind.
[4] Catches during 15 February–15 March, 1999 period used to approximate actual closures in 2001.

One-month closures from February to March will reduce catches by about 9.7% and annual revenues about 9–11%. A 2-month closure more than doubles these reductions such that a 2-month closure from 15 February through 15 April would result in about a 17–21% reduction in annual landings and a 20–23% reduction in annual revenues.

The implications of these reductions in revenues and employment rely on a number of factors which relate to the vulnerability or resilience of the industry as mentioned by McCay.[3] In this case, the consequences depend on 1) the fleet's ability, given existing regulations, to incur costs and switch to another species, gear, or fishery, 2) the impact on revenues and costs if the fleet displaces effort into time periods before or after the closure and causes prices to fall, 3) the wholesale market's ability to compensate for a 2-month supply interruption to restaurants and groceries without relying on imports, and 4) the ability of labor markets to respond to employment interruptions at all levels of the industry (harvest, wholesale, retail).

This industry, like all fresh food markets, operates at the ex-vessel (harvesting) level with a relatively small profit margin and a reduction in catches may move the harvesting and the wholesale sectors of the industry back and up along its long-run cost curve to a position of higher costs. Unless the fleet is able to switch to another fishery, these costs may not be able to be reduced in the short run by expanding catches. Because of previous regulations, options for switching in this case seem relatively limited and might require relocation for a stable group of owners and crew. Even assuming costs remain constant, the closure could result in an overall reduction in revenues. If the fleet is able to displace effort into other time periods before or after the closure, the displacement still may not compensate with the same revenues as those lost during the closure. There are other constraints such as weather (hurricanes) and availability of stock which would constrain this mobility into other time periods.

Erosion of a small profit margin with declining revenues combined with a 2-month supply interruption leaves the market open to entry of imports. With a 2-month closure, fish suppliers may lose buyers to imports which would impair their long-term ability to recover. The established industry in Madeira Beach, and the market which serves predominantly the surrounding geographical area, may be completely restructured by these closures. The various sectors are integrated and have historical economic relationships which implies that

Table 12.—Commercial grouper catches and revenues by gear type landed in Madeira Beach, 2000.[1]

Gear	Shallow-water species[2] Catch (lb)	Revenue ($)	Ex-vessel price ($)	Deepwater species[3] Catch (lb)	Revenue ($)	Ex-vessel price ($)
Bandit	75,090	171,738	2.29	1,132	2,803	2.48
Closure[4]	4,929	15,214	3.08	0	0	0
Longline	1,598,400	3,845,930	2.41	370,257	966,858	2.61
Closure[4]	165,712	463,458	2.80	28,357	81,556	2.88
Hook and line	253,928	634,978	2.50	1,619	3,455	2.13
Closure[4]	20,419	58,284	2.85	114	313	2.75
Unknown gear	65,233	130,739	2.00	3,363	12,379	3.68
Closure[4]	10,104	16,204	1.60	1,874	4,839	2.58
Dive	8,659	22,168	2.56	120	120	1.00
Closure[4]	493	856	1.80	0	0	
Total						
All gear	2,001,310	4,805,553	2.40	376,491	985,615	2.62
Closure[4]	201,657	554,016	2.75	30,345	84,708	2.79
Closure percent of yearly	10.1%	11.5%				
All gear, all shallow and deep species combined	2,377,801	5,791,168	2.44			
Closure[4]	232,002	640,724	2.76			
Closure percent of yearly	9.8%	11.1%				

[1] Source: Florida Fish and Wildlife Commission and Madeira Beach trip reports.
[2] Shallow-water grouper includes red, gag, black, yellowfin, yellowmouth, rock hind, red hind, scamp.
[3] Deepwater grouper includes misty, snowy, yellowedge, warsaw, speckled hind.
[4] Catches during 15 February–15 March, 2000 period used to approximate actual closures in 2001.

Table 13.—Summary of economic impacts of one month grouper closure on Madeira Beach.[1]

Item	Pounds	Revenue ($)
Direct Revenue Losses		
Estimates using 1999 landings (all gear)		
15 February–15 March	278,789	613,119
16 March–15 April	342,042	860,917
Total	620,831	1,474,036
Percent of total	21.6%	22.3%
Estimates using 2000 landings (all gear)		
15 February–15 March	232,002	640,724
16 March–15 April	180,613	518,805
Total	412,615	1,159,529
Percent of total	17.4%	20%
Direct employment losses from one month closure[2]		
33 Full-time jobs per year[3]		
Indirect effects on Pinellas County from one month closure[2]		
Employment loss over ten years: 319 jobs[4]		
Personal income losses over ten years: $10.4 million		

[1] Source: Compiled from data in Tables 11, 12, and REMI model output.
[2] Based on REMI computer model of west central Florida.
[3] Based on 441 vessel, crew, and fish dealer employees losing 1-month employment.
[4] Over 340 jobs are lost when effects are considered statewide over 10 years.

Table 14.—Ten-year impacts on employment and personal income in Pinellas County and the state of Florida from 1-month, 2-month, or 12-month closures of the grouper fishery in Madeira Beach.

Closure period	Impact Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
One month closure										
Pinellas County										
Employment	33.0	32.5	32.0	31.7	31.4	31.2	31.4	31.7	32.0	32.4
Personal income (Millions $)	0.7	0.8	0.9	0.9	1.0	1.1	1.1	1.2	1.3	1.4
State of Florida										
Employment	35.2	35.2	35.2	34.2	33.2	32.2	36.1	34.2	34.2	33.2
Personal income (Millions $)	0.9	1.1	1.1	1.1	1.2	1.2	1.3	1.3	1.6	1.6
Two month closure										
Pinellas County										
Employment	69.5	68.4	67.4	66.7	66.1	65.8	65.9	66.5	67.0	67.8
Personal income (Millions $)	1.4	1.6	1.8	2.0	2.1	2.2	2.4	2.5	2.7	2.9
State of Florida										
Employment	75.2	74.2	73.2	71.3	70.3	70.3	72.3	71.3	71.3	72.3
Personal income (Millions $)	1.8	2.1	2.3	2.4	2.6	2.6	2.8	2.9	3.2	3.4
Twelve month closure										
Pinellas County										
Employment	339.4	334.0	329.2	325.2	322.4	321.5	322.3	324.7	327.1	331.4
Personal income (Millions $)	6.9	8.0	8.9	9.6	10.2	10.9	11.6	12.3	13.1	14.0
State of Florida										
Employment	367.2	362.3	355.5	348.6	345.7	343.8	345.7	346.7	349.6	353.5
Personal income (Millions $)	8.7	10.2	11.1	11.8	12.5	13.1	13.9	14.7	15.6	16.5

changes in one sector will be felt in the other sectors. With restructuring, one or another sector of the industry (harvesting, wholesale) may no longer be profitable under the new condition.

If the industry in Madeira Beach could not recover, we estimated the loss from a 12-month or complete closure of the industry comprised of the vessels, crew, and dealers. These results are given in Table 14. A complete closure in Madeira Beach would result in losses to Pinellas County of 339 jobs per year and $6.9 million in personal income. Over 10 years, the losses would be 3,275 jobs and $105 million in personal income. Statewide, losses for a 12-month closure would be 367 jobs the first year and over 10 years, 3,518 jobs and $128 million in personal income.

Conclusion

This analysis provides new information for evaluation of community impacts of reef fish regulation in the Gulf of Mexico. The analysis provides an empirical estimate of the degree of disruption of economic relationships that might occur in the harvesting sector of the industry. The industrial organization approach provides information about the location of the disruptions relative to the level of the industry as well as, in this case, the geographical location.

The paper also points to additional research that could provide an even

deeper profile of fishery-related activity in Madeira Beach. That research might include demand analysis, anthropological assessment of industry relationships, and exploration of the role of imports, previous regulations, and different types of gear on this market.

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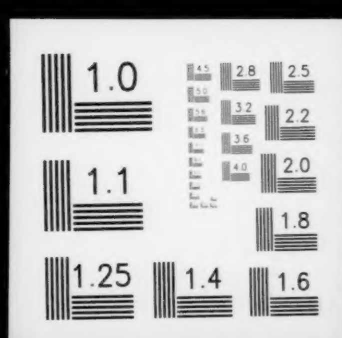
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